

CHANGES IN QUALITY MANAGEMENT APPROACHES FOR DESIGN-BUILD HIGHWAY PROJECTS

A Dissertation
Presented to
The Academic Faculty

by

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In Partial Fulfillment
of the Requirements for the Degree
Master of Science in
Building Construction and Facility Management

Georgia Institute of Technology
May 2018

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I would like to dedicate this thesis to my beloved family.

ACKNOWLEDGEMENTS

I would like to especially thank my advisor, Dr. Baabak Ashuri, and my colleague at the ESBE lab, Yasho Jallan, without whose guidance and encouragement I could not have reach the goal of this study. I would also like to thank my committees, Dr. Eunhwa Yang and Dr. Mounir El Asmar for their advice and support, which improved this study a lot.

I would like to express my deepest appreciation to my parents Myungsook Jeong and Seokjun Lee for their endless love, support, and trust. The support and faith that my sister and brother have provided me with have made my return to school worthwhile. I would like to especially thank my aunt Boksil Baek, without whom I would not have begun this journey in academia.

Special thanks to all representatives from state Departments of Transportation across the nation. This research would have not been possible without their generosity and continuous responses in sharing their expertise and experience for the past year and a half.

Lastly, I am grateful for the financial support from the Georgia Department of Transportation. I especially acknowledge and appreciate the help of Mr. Darryl VanMeter, GDOT Assistant P3 Division Director/State Innovative Delivery Administrator, and Ms. Monica Flournoy, GDOT Office of Materials Administrator, who provided practical insights and continuous feedback regarding real-time issues in quality management.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
SUMMARY	ix
CHAPTER 1. Introduction	1
1.1 Introduction	1
1.2 Regulations	2
1.2.1 23 CFR 637	2
1.2.2 FHWA Techbrief	3
1.3 Literature Review	6
1.4 Problem Statement	8
CHAPTER 2. Research methodology	9
2.1 Overview	9
2.2 Discussion of Research Methodology Steps	11
CHAPTER 3. Challenges	16
3.1 Overview	16
3.2 Reluctance to Shift the Responsibility of Quality Assurance to the Design–Build Team	17
3.3 Reluctance of Contractor to Accept the New Role of QA in the DB Environment	18
3.4 Developing an Appropriate Quality Management for the Alternative Delivery When Detailed Design and Actual Quantities are Not Available	19
3.5 Developing an Adequate and Reliable Budget for Quality Management Tasks and Conducting Cost Control	19
3.6 Differences in Terminology Used by Each State DOT for Quality Management	21
3.7 Lack of a Unified and Consistent Guidebook for Quality Management Across all State DOTs	22
3.8 Differences in Organizational Structure of DOTs for Quality Management	23
3.9 Understanding New Roles and Responsibilities in Design–Build Projects	24
3.10 The Need for Specialized Training to Provide New Skills and Qualifications	25
3.11 The Need for System for Evaluating the Qualifications of the Design–Build Team and Its Approach Toward Quality Management in the Procurement Phase	26
3.12 Lack of Familiarity Regarding the Use of Contractor Samples in the Acceptance Procedure	27

CHAPTER 4. Practical Componentets of the Quality Assurance system	28
4.1 Acceptance Approaches	28
4.1.1 Approaches for Quality Acceptance	29
4.1.2 Decision Factors	32
4.2 Selection Criteria	36
4.2.1 RFQ Phase	36
4.2.2 RFP Phase	37
4.2.3 Quality Management Plan	38
4.3 Independent Assurance	41
4.3.1 Project Approach	42
4.3.2 System Approach	42
4.3.3 Mixed Approach	42
4.3.4 Summary of the Interview Findings about the State of the Practice in IA Approaches	43
4.4 Non-Conformance Reports (NCRs)	46
4.4.1 Summary of the Interview about the State of the Practice in the NCR Process	48
4.5 Cost Mechanism	49
4.5.1 Summary of the Interview Findings about Cost Mechanism for Quality Management Tasks in the Design–build Environment	50
4.6 Pay Factors	52
4.6.1 Summary of the Interview Findings about Pay Factor Adjustment	52
CHAPTER 5. Discussion	56
CHAPTER 6. CONCLUSIONS	63
APPENDIX A. Detailed interview questions	66
A.1 First round of Interview Question	66
A.2 Second round of Interview Question	66
A.3 Third round of Interview Question	67
A.4 Fourth round of Interview Question	67
A.5 Fifth round of Interview Question	68
A.6 Sixth round of Interview Question	68
A.7 Seventh round of Interview Question	69
REFERENCES	70

LIST OF TABLES

Table 1	– States with Percentage-based Mechanism for Budgeting QA Services in Design–Build Projects	51
Table 2	– Line Items for Pay Factors	54
Table 3	– Material Tests for Pay Factor	55

LIST OF FIGURES

Figure 1	– Proper use of term "Quality Assurance"	5
Figure 2	– Quality assurance elements (FHWA 2008)	5
Figure 3	– Six core elements of QA	6
Figure 4	– Research methodology	10
Figure 5	– Overview of email interview	12
Figure 6	– Three acceptance approaches	30
Figure 7	– Typical organizational chart of a DB project involving a mixed approach (Recreated from the GDOT Quality Assurance Plan)	31
Figure 8	– Distribution of state DOTs based on their acceptance approaches	33
Figure 9	– Consistency of acceptance approaches	34
Figure 10	– Decision factors of acceptance approaches	36
Figure 11	– Shortlisting criteria in RFQ phase	37
Figure 12	– Proposal evaluation in RFP phase	38
Figure 13	- Distribution of state DOTs based on their IA approaches	45
Figure 14	- Consistency of IA approach	46
Figure 15	- Non-validation flowchart (Recreated from Arizona Department of Transportation 2016)	48
Figure 16	- Implementation of NCRs	49
Figure 17	– Mechanism for budgeting QA services in design–build projects	51
Figure 18	- Implementation of pay factors	54

SUMMARY

Conducting quality assurance programs for design–build (DB) highway projects represents new challenges for state departments of transportation (DOTs). With DB projects, highway agencies have experienced a decrease of experienced staff, which has led to a loss of direct control over agencies’ day-to-day quality activities. Although quality-related tasks are similar for both design–bid–build (DBB) and DB projects, the roles and responsibilities are differently assigned to the stakeholders depending on the requirements indicated in solicitation documents. Considering these changes, DOTs are struggling with this shift of responsibilities, the new role of quality assurance (QA), the reliability of budgeting, and the lack of unified terminology and a guidebook, and so forth. This study will examine the state-of-the-art practices in quality management for highway construction projects that are actively using DB to achieve the main objective, which is to determine changes in quality management approaches of DB highway projects compared to those in DBB projects.

Identifying the existing challenges in the quality management procedures in the alternative delivery environment with a strong focus on DB projects requires conducting a content analysis. This involved reviewing regulations, FHWA policy documents, quality manuals, and state DOT solicitation documents. A DB project delivery system is a significant change from the traditional DBB system, which include the following differences: A large number of roles and responsibilities are transferred by the state DOT to the design–builder. The size of the project is usually much larger. The cost and funding mechanisms are much more elaborate. The personnel qualifications and requirements have

to be carefully reviewed at each stage. In addition, several stakeholders are involved in the project. These differences in the DB approach come with several challenges:

- Reluctance of state DOTs to shift the responsibility of quality assurance (QA) to the design–build team
- Reluctance of contractor to accept the new role of QA in the DB environment
- Developing an appropriate quality management for the alternative delivery when detailed design and actual quantities are not available
- Developing an adequate and reliable budget for quality management tasks and conducting cost control
- Differences in terminology used by each state DOT for quality management
- Lack of a unified and consistent guidebook for quality management across all state DOTs
- Differences in organizational structure of DOTs for quality management
- Understanding new roles and responsibilities in design–build projects
- The need for specialized training to provide new skills and qualifications
- The need for a system for evaluating the qualifications of the design–build team and its approach toward quality management in the procurement phase
- Lack of familiarity regarding the use contractor samples in the acceptance procedure

To obtain a deeper understanding of the state of the practice in state DOTs and to identify best practices in handling the identified challenges for implementing a quality management plan for the alternative delivery environment, this study conducted structured

interviews of DOT personnel and industry experts. The results of the email interview process and the responses to the follow-up questions helped identify several important areas for improvement in quality management:

- Acceptance approaches and decision factors in choosing the most appropriate acceptance approach for the design–build project
- Selection criteria and quality management plan
- Independent assurance methods
- Non-conformance reports (NCRs)
- Cost mechanism
- Pay factor adjustment

The results indicate that responsibility for quality assurance is being transferred to design-build teams. The findings of this research show that some DOTs use a consistent approach to quality assurance management, and other DOTs tend to change their approach depending on the project size, staff availability, agency experience, and so forth. This study attempts to identify changes in quality assurance practices and present the factors that influence the selection of a quality management approach for DB highway projects.

CHAPTER 1. INTRODUCTION

One of the fastest growing alternative project delivery methods used in the United States is design–build (DB). A study conducted by the Design-Build Institute of America (DBIA) indicates that since 2002, the number of projects in the transportation industry procured with DB in the United States has increased 600%. In 2017, the DBIA announced that DB had been fully authorized in 27 states and the District of Columbia. There are only four state DOTs that do not have the authority to use DB in highway project delivery.

1.1 Introduction

DB contracting is becoming popular because of time and cost savings compared to the traditional design–bid–build (DBB) method. With traditional DBB, departments of transportation (DOTs) need to handle separate contracts with a designer and a contractor. This limits the flexibility of executing construction work before the completion of the design. In DB projects, however, the owner signs a contract with a single combined entity as a designer and a contractor. Coordinating the schedule of the projects with the single team allows the design–builder to initiate their construction work before the design phase is complete, which saves costs and reduces time. Despite these advantages, DOTs have faced several challenges in implementing DB contracting. One specific problem is with contract documents, which do not include clear descriptions of differences in the roles and responsibilities of the stakeholders. One example of this confusion is the role of the engineer of record (EOR), who works for the design–builder, and the design–builder assumes the liability of performance in DB projects, which differs from the EOR’s role in traditional DBB projects.

Most articles, such as that of Munns and Bjeirmi (1996), Chan et al. (2002), Chan et al. (2004), and Songer et al. (2015), identified and discussed the iron triangle of project success criteria. One of the essential criteria of this iron triangle to achieve project success is quality (Chan et al. 2002). Bubshait and Almohawis (1994) defined quality as general conditions that enhance materials and workmanship in accordance with project requirements (Chan et al. 2002). If the material and workmanship lack quality, this may fail to comply with specifications and contract requirements, which could lead to project failures such as cost overruns and delayed schedules on a highway project. State departments of transportation (DOTs) recognize the importance of quality assurance (QA) of their materials and construction (Charles S. Hughes 2005). As early as 1995, the federal government revised Title 23, Part 637, Code of Federal Regulations (23 CFR 637), which requires each state DOT to develop their own quality assurance program that assure the materials and workmanship for each federal-aid highway construction project (Code of Federal Regulation, title 23, sec.637.205). However, Gransberg and Molenaar (2008) examined DB procurement packages and found that 23 of 60 requests for proposals (RFPs) did not clearly define roles and responsibilities. To obtain a quality product, the DOTs need to clearly state quality-related roles and responsibilities in the contract document (Gransberg et al. 2008).

1.2 Regulations

1.2.1 23 CFR 637

In the last few decades, the methods and procedures relating to quality assurance management have undergone several changes with the introduction of alternative delivery

such as design–build (DB) in transportation projects. In 1990, the Federal Highway Administration (FHWA) established Special Experimental Project 14 (SEP-14) to utilize alternative approaches for delivery of highway projects (FHWA 2006). In 1995, Title 23, Code of Federal Regulations, Part 637 (23 CFR 637) allowed states highway agency (SHA) to use the testing results from contractors (design–builders) in acceptance decisions if they are verified by their agencies or designated representatives (FHWA 2004). In addition, the federal code that deals with QA procedures for construction (23 CFR 637 Subpart B) requires that each SHA develop a QA program for the national highway system. This ensures that materials and workmanship integrated in every federally funded highway construction project conform to the approved plans and specifications of the project. However, QA practices vary from state to state, and the practice for one DOT may not be acceptable for other DOTs (Scott and Molenaar 2017). To reduce this inconsistency and clarify quality management, the Federal Highway Administration published the quality management guidelines.

1.2.2 FHWA Techbrief

In 2004, in response to revised regulations, the FHWA published a technical advisory that “provide[s] guidance and recommendations for the use and validation of contractor’s test results for acceptance.” In 2008, the Transportation Construction Quality Assurance Reference Manual (FHWA 2008) indicated that the transportation industry has moved away from the term “quality control/quality assurance (QC/QA)” (or “QA/QC”) to refer to a quality assurance program. Some transportation agencies have historically applied QC/QA, indicating that QC represents a contractor’s responsibility and that QA is an agency’s responsibility (see Figure 1). However, quality control is not a separate function

from quality assurance. Instead, QC is one of the core elements of a quality assurance program. Thus, QA refers to an overall system for assuring project quality. In response to these changes, to help clarify roles, responsibilities, and quality-related activities when DOTs use DB contracting, the FHWA (2012) published a Techbrief titled, “Construction Quality Assurance For Design-Build Highway Projects.” The Techbrief recommends that DOTs use synthesized quality management programs by implementing quality assurance as an umbrella term with six core elements (see Figure 2): (1) QC, (2) quality acceptance, (3) independent assurance (IA), (4) personnel qualification, (5) laboratory accreditation, and (6) dispute resolution.

Among the six core elements, QC, acceptance, and IA are primary activities (see Figure 3). QC activities, including sampling, testing, and inspection, are performed by design-builders. Acceptance is defined as “all factors used by the agency (i.e., sampling, testing, and inspection) to evaluate the degree of compliance with contract requirements” (FHWA 2012, p. 3), which is the responsibility of the DOTs or their designated agents. IA provides an independent assessment of QC and acceptance activities that ensure that all factors are accurate and that the testing equipment used in the program is functioning and remains calibrated (FHWA 2012). The remaining three activities support the QA program. To ensure the achievement of quality, qualified personnel should perform testing and inspection in a capable laboratory. To strengthen these elements, a dispute resolution system provides resolution of possible discrepancies between the QC data of design-builders and acceptance data from highway agencies.

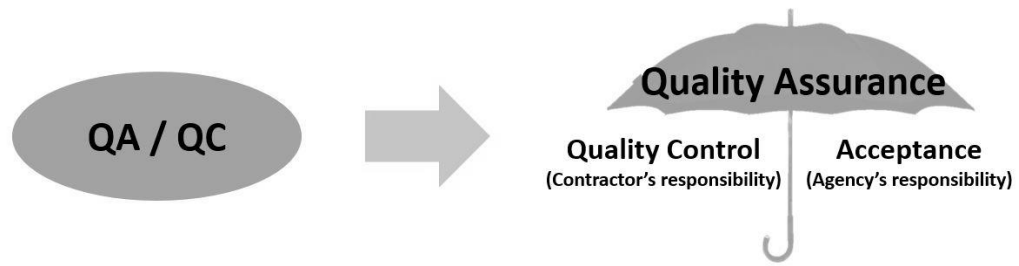


Figure 1 – Proper use of term "Quality Assurance"

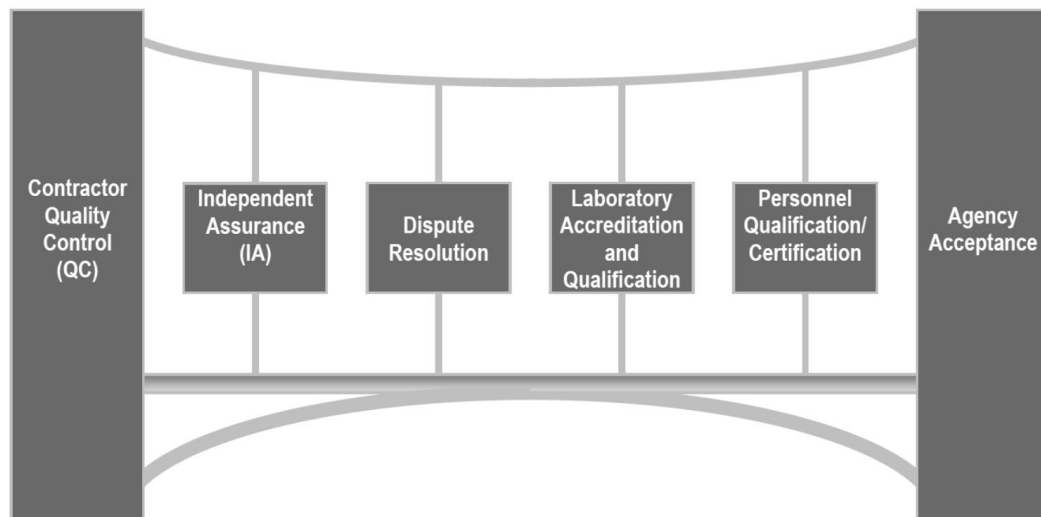


Figure 2 – Quality assurance elements (FHWA 2008)

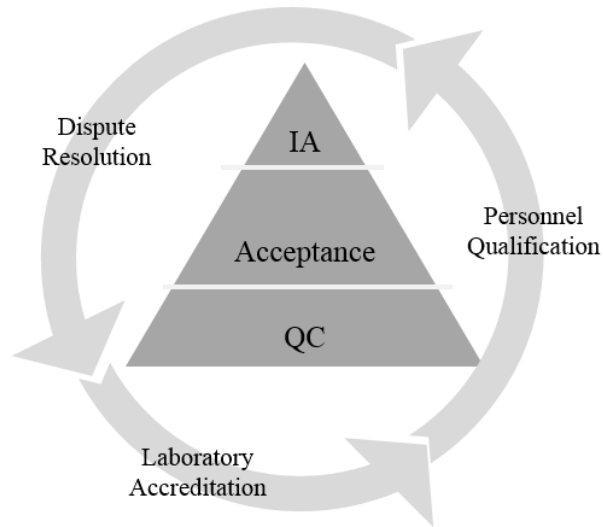


Figure 3 – Six core elements of QA

1.3 Literature Review

The literature review addresses the importance of the contract documents that should include clear roles and responsibilities in terms of quality management because those roles and responsibilities of stakeholders in DB project are different from those in traditional DBB projects. The main difference lies with those who hold the responsibility (Gransberg et al. 2008; Gad et al. 2015). On DBB projects, the staff of the DOTs are mainly responsible for inspection, QA verification and acceptance determination, and independent assurance. Compared to the contractor on typical DBB projects, those on DB projects have the primary responsibilities for quality management, including design and construction. DOTs just perform QA oversight verification testing and independent assurance (Gransberg et al. 2008).

By reviewing the solicitation documents, Gransberg and Molenaar (2004) identified different approaches of six owners during the evaluation phase. This shows that there is no single way to distribute and assign quality management responsibilities across all DB projects (Gransberg et al. 2008). Therefore, it is important that roles and responsibilities should be clearly stated in the solicitation documents (Gransberg et al. 2008). Gransberg and Molenaar (2008) continued their study of solicitation documents and found that 23 of 60 requests for proposals (RFPs) did not clearly define the roles and responsibilities. The DOTs need to clearly state quality related roles and responsibilities in the contract document to obtain a quality product (Gransberg et al. 2008).

Different approaches toward quality management are also revealed by a case-study conducted by Harman and Sillars (2013). They explored ten transportation projects with four different project delivery methods and found different QA practices that are not generally applied in the traditional DBB projects. They determined that these newer QA practices, mostly used for alternative project delivery methods such as DB, may be a key factor for project managers to consider when they develop a whole quality assurance system. Kraft and Molenaar (2013) developed different types of the quality assurance organization (QAO) process based on project specifications. They identified five fundamental QAOs in the industry (Kraft et al. 2014). They continued their work in another paper (Kraft and Molenaar 2015) in which they identified 10 factors that influence the QAO selection process, including project size, project complexity, and schedule. Gad et al. (2015) claimed that state DOTs had become more cognizant of the importance of quality management in their DB contracting process. To help clarify the roles and responsibilities related to quality assurance program on DB projects, the FHWA published the Techbrief,

titled “Construction Quality Assurance For Design-Build Highway Projects.” This recommends DOTs to include six core elements—QC, quality acceptance, independent assurance, personnel qualification, laboratory accreditation, and dispute resolution—in their quality assurance program (FHWA 2012).

1.4 Problem Statement

It is important to include and apply QA core elements that are practical components implementing quality management program of state DOTs. Although DOTs include six core elements in their quality assurance program, the practices of QA vary from state to state, and the practice for one DOT may not be acceptable for other DOTs (Scott and Molenaar 2017). It is necessary to investigate different practices in all QA core elements across all DOTs that are actively using DB projects and identify challenges in implementing their quality assurance program. To obtain a better understanding of the current state of the practice in quality management among state DOTs, this study conducted a combination of interview and a content analysis. The primary objective of this study is to determine gaps in practices between DBB and DB and identify current challenges associated in QA for DB highway projects. The results show that the responsibility for quality assurance is being transferred to design-build teams. Some DOTs use a consistent approach to quality assurance management, and other DOTs tend to change their approach depending on the project size, staff availability, agency experience, and so forth. This study attempts to present the state-of-the-art practices in quality management across DOTs and identify key factors that influence the selection of their quality assurance approaches.

CHAPTER 2. RESEARCH METHODOLOGY

2.1 Overview

Because of the nature of this topic, this study used a combination of methods. An overview of the research methodology is presented in Figure 4. The overarching objectives of this research were to: (a) identify the key challenges faced by state DOTs to develop and implement an effective quality management approach in design–build projects, and (b) determine appropriate strategies to enhance quality management in the design–build environment. To achieve these objectives, this study took the following steps:

1. Conduct an extensive review of the academic and professional literature related to quality management for alternative project delivery and identify key challenges
2. Create open-ended questions for distributing via an initial emailed questionnaire
3. Refine the questions by conducting a dry-run interview with selected subject-matter experts to ensure that the questions are clearly crafted and the anticipated responses reflect the intent of the research
4. Distribute the questionnaire with subject-matter experts in state DOTs and follow up with them to receive as high a response rate as possible
5. Determine the areas to prepare questions for follow-up phone interviews and/or emails
6. Follow up with agencies that best responded to the initial questionnaire to conduct multiple rounds of structured interviews and/or emails

7. Collect documents from state DOTs following the interviews/emails (e.g., design–build and public–private partnership [P3] manuals, state DOTs’ quality management plans for design–build and P3 projects, request for qualification (RFQs) and request for proposals (RFPs) of past and current design–build and P3 projects, and master contracts and related task orders with the owner’s consulting firms offering quality management and construction engineering and inspection [CEI] services) and analyze the contents of these documents in several areas of interest, such as common practices in quality management organization and the quality assurance process
8. Summarize and present the findings from all the information collected through emails, structured interviews, and content analysis

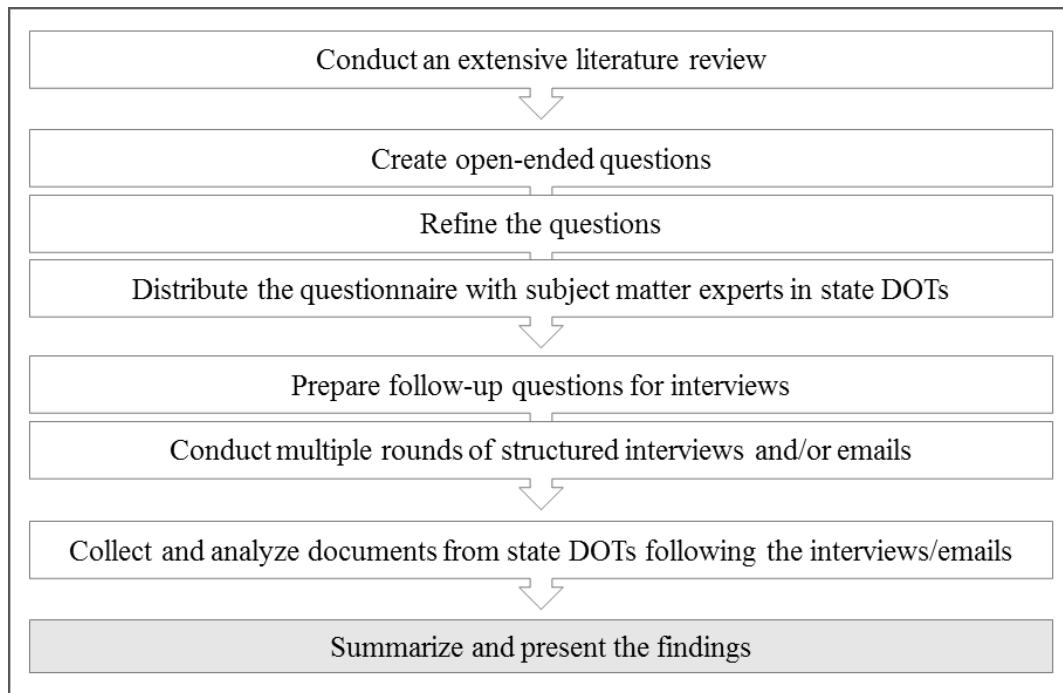


Figure 4 – Research methodology

2.2 Discussion of Research Methodology Steps

1. *Conduct an extensive review of the academic and professional literature related to quality management for alternative project delivery and identify key challenges:* As the beginning of the research process, literature review tasks aimed to examine the current state of the practice in quality management among state DOTs that are actively using DB and DBB projects, and identify key differences and challenges in quality management practices in DBB versus DB projects.
2. *Create open-ended questions for distributing via an initial emailed questionnaire:* As the first step to better understand the practice of quality management among state DOTs in the alternative delivery environment, a set of initial question was developed. The areas of focus for initial questions were:
 - a. key differences in implementing quality management between DBB and alternative delivery environments,
 - b. the main issues for successful execution of quality management in the alternative delivery environment,
 - c. the availability of quality management manuals for DB and P3 delivery systems, and
 - d. an overview of quality management organization for DB and P3 delivery systems.
3. *Refine the questions through conducting dry-run interviews with selected subject-matter experts to ensure that the questions are clearly crafted and the anticipated responses reflect the intent of the research:* The questions were sent to several innovative delivery subject-matter experts, such as the heads of the offices of

innovative delivery program in several state DOTs across the nation, in order to validate and refine the questions and make a final decision on the best questions to use in the initial emailed questionnaire to get the best results. The study then used the refined set of questions to gain and collect information about the current practices of quality management in the alternative delivery environment.

4. *Distribute the questionnaire with subject the questionnaire with subject-matter experts in state DOTs and follow up with them to receive as high a response rate as possible:* The email survey was initially targeted to 40 state DOTs in the United States with active design–build programs based on the study conducted by the DBIA in 2017 (DBIA 2017). This survey was sent to the manager-level of personnel such as the heads of the offices of innovative delivery program from the relevant department at each DOT. The initial survey was conducted in March 2017, 27 state DOTs provided answers for the initial interview (see Figure 5).

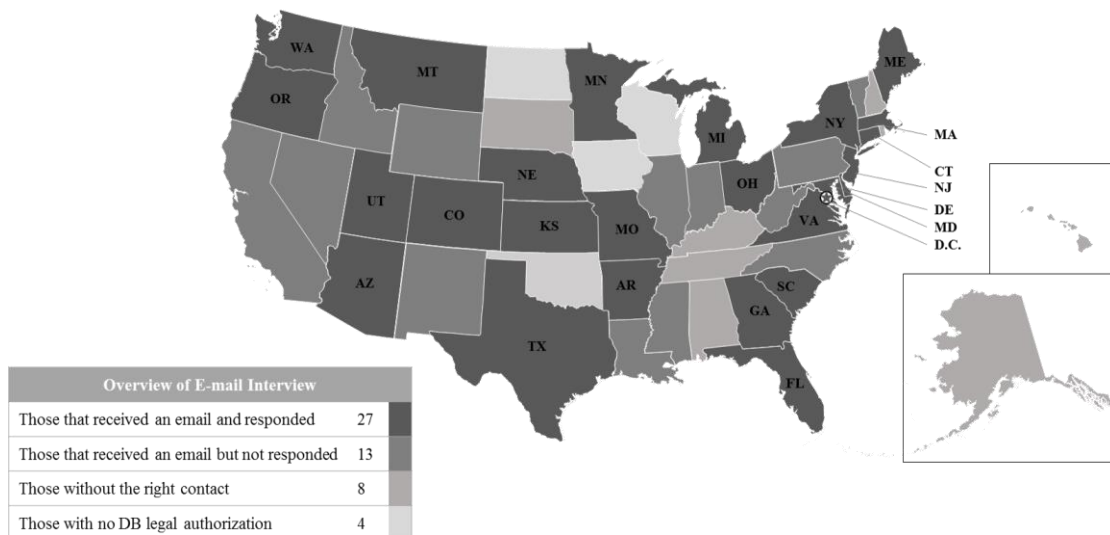


Figure 5 – Overview of email interview

5. *Determine the areas to prepare questions for follow-up phone interviews and/or emails:* The follow-up interview/email phases included more detailed questions to better understand the practice of quality management among state DOTs in the alternative delivery environment. The areas of focus for follow-up questions were:
- a. the relative significance of challenges for executing quality management in the alternative delivery environment,
 - b. further description of QA organizational models and new roles and responsibilities required for QA in the DB and P3 delivery systems,
 - c. handling quality management issues during shortlisting and proposal evaluation phases,
 - d. approaches used by agencies for independent assurance and quality acceptance,
 - e. budgeting and cost control methods for quality management services, and
 - f. methods to resolve conflicts related to quality issues and non-conforming products.

This study refined the follow-up interview/email questions through conducting dry-run interviews with a few subject-matter experts in design–build organizations, including the above-mentioned state DOTs, to ensure that the questions would help collect the information they intended to retrieve from the state DOT officials.

6. *Follow up with agencies that best responded to the initial questionnaire to conduct multiple rounds of structured interviews and/or emails:* Following the analysis of the initial emailed questions, 19 representatives from each state DOT were identified for the six-round of follow-up interviews: Arizona, Colorado,

Connecticut, Florida, Georgia, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Ohio, Oregon, South Carolina, Texas, Utah, Virginia, and Washington State. The selection was made based on the quality and depth of answers to the survey questions, as well as expressed interest by the respondents to participate in the following research steps. On average, 10 to 11 representatives from each DOT that responded to the initial interview replied to each follow-up survey.

7. *Collect documents from state DOTs following the interviews/emails (e.g., design–build and P3 manuals, state DOTs’ quality management plans for design–build and P3 projects, RFQs and RFPs of past and current design–build and P3 projects, and master contracts and related task orders with the owner’s consulting firms offering quality management and CEI services) and analyze the contents of these documents in several areas of interest, such as common practices in quality management organization and quality assurance process:* Participants in the follow-up interviews/emails provided several internal documents that contained valuable information regarding the quality management plan of their alternative delivery programs. Also, they shared copies of their contracts with the owner’s consulting firms that were assisting them in preparing quality management plans and conducting CEI services. These documents explain how the state DOT handles various aspects of quality assurance/quality control for design–build and P3 projects. These documents included, but were not limited to, design–build and P3 manuals, quality management plans for design–build and P3 projects, RFQs and RFPs of past and current design–build and P3 projects, and master contracts and

related task orders with the owner's consulting firms offering quality management and CEI services. Content analysis was performed on the resources provided to: (a) understand state DOTs' main issues in handling quality management in the alternative delivery environment, and (b) identify and characterize different state DOTs' practices in developing and implementing quality assurance plan for design-build and P3 projects.

8. *Summarize and present the findings of all the information collected through emails, structured interviews, and content analysis:* In the final step of the research methodology, all the work done in the earlier stages was assembled in an efficient manner to come up with a synthesis of all the findings. Starting from the first step of conducting extensive literature review for finding gaps in existing research and coming up with questions for subject matter experts, to distributing the questionnaires over email and following up with these contacts over a protracted period of time with questions on several pertinent issues, and performing content analysis on all the responses and documents shared by the interviewees.

CHAPTER 3. CHALLENGES

3.1 Overview

Alternative project delivery methods such as DB expand the contractor's role in construction quality management by including conventional quality control activities of the contractor and several QA tasks that traditionally performed by DOT personnel. This change results in different practices regarding the roles and responsibilities for various elements of the construction QA program across states. To clarify the roles and responsibilities regarding quality assurance program and comply with 23 CFR 637 and the FHWA's Techbrief (2012), a comprehensive construction quality assurance program should consist of six core elements: (1) quality control, (2) acceptance, (3) independent assurance, (4) dispute resolution, (5) personnel qualification, and (6) laboratory accreditation/qualification. Use of an alternative delivery method does not diminish the need to perform any of these functions; however, the party performing them may differ from the DOT's standard practices. Possible options include performance by the DOT, an independent evaluator, the contractor (with DOT verification sampling and testing), or some combination thereof.

With the introduction of alternative delivery in transportation projects, the methods and procedures relating to quality management have undergone several changes that introduce new challenges for state DOTs in efficient and effective execution of quality management in the alternative project delivery environment. In addition, state DOTs have limited resources for keeping up with the demand of large-scale DB projects. Based on the findings of the interview and content analysis of the documents provided by the state DOTs

interviewed, this chapter presents the identified challenges for developing and implementing quality management in the alternative project delivery.

3.2 Reluctance to Shift the Responsibility of Quality Assurance to the Design–Build Team

Since project costs and sizes have grown exponentially over the last couple of decades, alternative project delivery methods such as DB becomes popular. With these project delivery methods, a large portion of the project responsibilities are shifted to the design–builder. However, the fact that a lot of responsibilities are now shouldered by the design–builder creates an interesting challenge for some state DOTs, as they may argue that this change has led to a lack of day-to-day control over the project as in the design–bid–build environment. A mental shift is needed for some DOT professionals to become accustomed to the new dynamics of the design–build project delivery. It is critical for state DOTs to understand the risk that extensive involvement in day-to-day quality assurance activities increases the risk that the design liability is shifted back to the agency from the design–builder. This is completely against the main feature of the design–build project delivery system that demands the role of the engineer of record remains with the design–build entity.

The idea of transferring some responsibilities that have been traditionally held by the state DOTs to the design–builder can be a big challenge. State DOTs have different levels of transfer of responsibilities to the design–builder. Some DOTs require that the design–build team follow the state’s official quality assurance manual, while others require the design–builders to present their own QA manual as a part of the selection process. A wide

variation also is seen in the roles of quality acceptance. Traditionally, all the acceptance has resided with the state DOT, but with the introduction of design–build and other alternative project delivery methods, the responsibilities of acceptance also have seen a shift. Understanding the shift in roles and responsibilities of the quality management team can be a source of challenge for some DOTs that may be afraid of losing control over day-to-day activities of the project.

3.3 Reluctance of Contractor to Accept the New Role of QA in the DB Environment

In the traditional design–bid–build environment, the state DOT accepts the quality assurance role and conducts inspections and testing to accept the contractor’s work. Contractors are familiar and comfortable with the conventional QA process, especially when they know that the liability is transferred to the owner once the work is accepted. This is aligned with the fact that the designer of record works directly for the state DOT and the contractor does not assume any design liability risk. Some contractors have difficulty changing their mindsets when they work in the design–build environment. Accepting new roles in the quality assurance program for the design–build project can be problematic for the design–build team. The major challenge that makes some design–builders uncomfortable is that the design and construction liability is not over immediately after the completion of the work element. Since the designer of record works directly for the design–builder, the liability of design remains with the design–build team and, therefore, the contractor needs to be more cautious than ever to deliver the total project with the anticipated level of performance as outlined in the design developed by the design–build team. Lack of adequate resources or trained personnel, and difficulty in changing the mindset are the main challenges that some contractors face with the new QA

model. Oftentimes, the fear of something new can also be a deterrent to trying out newer approaches. Some contractors might be reluctant to change their traditional roles and responsibilities because they firmly believe the statement, “Don’t fix what’s not broken.”

3.4 Developing an Appropriate Quality Management for the Alternative Delivery When Detailed Design and Actual Quantities are Not Available

Most design–build projects are lump-sum contracts based on partially completed design. Detailed design and actual quantities of major line items are not available at the time that the design–builder comes on board (i.e., the design–builder develops the cost estimate based on estimated quantities of different line items that will change throughout the detailed design development). Lack of detailed information about design elements and the actual quantities of different line items makes it challenging for state DOTs and design–build contractors to define a quality management program. Traditionally, the QA program is required to comply with specifications from each DOT. These specifications are defined based on types of tests and respective frequencies and timing of the tests that can be exactly quantified using detailed design information in the design–bid–build project. This way is easy to track the work progress. The quality management program for unit price design–bid–build contracting needs to be revisited to accommodate the nuances of lump-sum design–build contracting. This change introduces challenges for some DOTs and contractors that may find it difficult to work in uncertain conditions with incomplete design information.

3.5 Developing an Adequate and Reliable Budget for Quality Management Tasks and Conducting Cost Control

In the traditional design–bid–build environment, state DOTs are in charge of allocating adequate resources and budgets for required QA tasks. State DOTs use the actual quantities of the work items and apply their historical rates to develop a good estimate for the QA budget. This approach is inherently limited in the design–build environment when detailed design and actual quantities for major line items are not available. Therefore, developing a reliable budget for design–build projects is a challenging task considering several unknown and uncertain factors involved in the QA process. This issue can become more challenging with the recognition that the design–build team will be in charge of conducting most of the quality management tasks in the alternative delivery environment. Some design–builders may be not as familiar as the state DOT quality management personnel in identifying required resources and estimating an adequate budget for QA tasks in the alternative delivery environment. Further, some DOTs may find it difficult to not have control over the design–build team’s expenditure of project funds on quality management tasks.

In lump-sum design–build projects, design–builders are not typically required to identify a separate line item for quality management tasks. Some state DOTs are concerned that the design–build team may not have enough expertise to develop a reliable budget for QA tasks or may not allocate a satisfactory budget for performing QA tasks. For instance, Missouri DOT reported that for design-build projects where contractors are responsible for QA and its budgeting, the DOT reviews the amounts identified in the work breakdown structure and ensures that the contractor has adequate resources budgeted for QA before approving the final schedule and work breakdown structure. Another point to note is that all the states interviewed reported that they do not require their design-builders to spend at

least an ‘x%’ of the project costs on QA. Most of these state DOTs are not interested in the exact budget details as long as the design-build team adheres to all QA tasks promised in the quality management plan for the alternative delivery environment.

3.6 Differences in Terminology Used by Each State DOT for Quality Management

The FHWA Techbrief recommends that each state outline a quality assurance management plan for its design–build projects. The plan should contain elaborated details on all six core areas of construction QA. However, the current terminology used throughout the country contains several inconsistencies. This inconsistency is a major challenge that the transportation design–build industry faces in dealing with quality management issues of alternative delivery projects. The terminology used in quality management manuals of some state DOTs, such as Texas DOT is highly consistent with that of the FHWA Techbrief recommendations. All six core elements of the QA plan are discussed thoroughly in those DOT guidelines. However, there are other state DOTs (e.g., Virginia DOT) that prefer to use their own convention when it comes to the terminology used for quality management. Although the technical terms used in these state DOT manuals are somewhat different than those used in the Techbrief, the principles behind the state manuals are consistent with the essence of quality management recommended by the Techbrief. However, these states do not use ‘quality assurance’ as an umbrella term; rather, they follow the historic QA/QC terminology, which traditionally associates QA to the agency’s role and QC to the contractor’s role. It should be noted that in design–build projects, where several quality management responsibilities lie with the design–builder, QA can be erroneously referred to as ‘quality acceptance’ as opposed to ‘quality assurance’.

3.7 Lack of a Unified and Consistent Guidebook for Quality Management Across all State DOTs

It is recognized that state DOTs have different approaches when it comes to guidebooks and quality management manuals for projects delivered under alternative delivery. Some state DOTs have developed quality management manuals that design-builders are required to follow. This serves as a minimum requirement on all their design-build projects for quality management purposes. Other states tend toward a different approach in which the state DOT requests the design-build team to propose a quality assurance plan for the design-build project and the state DOT evaluates the plan during the selection phase. The transportation design-build industry is facing a challenge in handling different quality management expectations while working with different DOTs across the nation.

The QA practice varies among different projects within the same state, as well. An example is found from the response from the Colorado DOT (CDOT) to one of the follow-up email questions:

“Historically on design-build projects CDOT has given the responsibility of both Quality Control and Quality Assurance to the contracting team. CDOT then performs Assessments on design and construction, as well as Independent Assurance materials testing. On the I-25 Ilex project CDOT chose to have the contracting team perform Quality Control, while CDOT retained the Quality Assurance program including Independent Assurance. It was decided that by

retaining the QC CDOT would have more control and oversight of the work performed during design and construction.”

3.8 Differences in Organizational Structure of DOTs for Quality Management

The roles and responsibilities for various elements of the QA program differ significantly across different states in the design–build environment. The main difference between traditional DBB projects and DB projects lies with those who hold the responsibility (Gad et al. 2015; Gransberg et al. 2008). With traditional DBB projects, the contractor is responsible for quality control to ensure that it is delivering a project that complies with its drawings and specifications. According to the FHWA, the responsibility for quality acceptance and oversight lies with the highway agency or its representative. The third-party firms do not typically become involved in the quality management. In DB contracting, while the process of quality control, which lies with the design–builder, is similar to DBB projects across the DOTs, this research found that the acceptance decisions of the DOTs vary from state to state based on the levels of owner involvement in acceptance because of involvement of the third-party firms and increasing responsibilities that are shifted to the design–builder.

Because of these changes in roles and responsibilities, the organizational structure for quality management in DB projects has changed and varies from state to state. New roles and responsibilities have changed the organizational structure in the DOTs. Clear understanding of the new organizational structure for quality management programs represents an important goal for state DOTs and the transportation design–build industry. Managing relationships among several parties involved in the quality management

program is a challenge for state DOTs in design–build projects. Maintaining healthy working relationships throughout the project is a necessity for the smooth execution of quality management tasks throughout the project development.

3.9 Understanding New Roles and Responsibilities in Design–Build Projects

In conjunction with the previous section, an important hurdle that is introduced in the organizational setup of quality management in design–build projects is the involvement of new entities in the process, e.g., independent quality firms (IQFs) and owner’s verification firms (OVFs). The IQF is usually hired by the design–builder with the consent of the owner. The IQF acts independently as a second line of acceptance. The IQF is assigned to verify that the quality control measures taken by the design–builder are up to the mark, the requisite material testing results are within the recommended guidelines, and the personnel working on the site are qualified and correctly certified. The OVF is hired by the owner to assist in the verification process. This can sometimes be seen as the last layer of quality acceptance and can also be tasked with the roles and responsibility of independent assurance.

Introducing these new players, and the various ways in which different state DOTs define their roles and responsibilities, may be problematic for some state DOTs and members of the transportation design–build industry. Clear understanding of the responsibilities and accountabilities of the new entities is critical to the success of quality management in the design–build environment. The existence of several players in the design–build project should not be treated as a source of confusion but as a core strength of the quality management organization with several layers of checks and balances. There

might be a perception of a shift in acceptance liabilities from design–builder to the IQFs and independent assurance responsibility from the owner to the OVF. This issue is crucial to overcome from the start of the project to avoid finger pointing if problems do arise.

The independent quality firm is typically hired by the design–build team with the consent of the owner. The IQF is part of the design–build team and is paid directly by the design–build contractor. However, it is critical that the IQF has the ultimate authority to act on the best interest of the project and protect the owner’s performance expectations in the design–build project. However, some IQFs may find it challenging to act as an impartial agent, as the design–build team may not hire them for future projects if they are very strict in their roles. Some IQFs may prefer to be hired directly by the owner and report directly to the owner. Also, some owners may find it difficult to become accustomed to the new arrangement in which the IQF works directly under the design–build contractor. However, most DOTs already overcome this challenge through rigorous examination of the proposed quality management plan of the design–build team to ensure that the right and most highly qualified IQF is selected to work on the project and has adequate power and authority to handle the quality issues in the design–build project. It is worth noting that, ultimately, all players in the design–build team, including the IQF, should work to satisfy the required expectations of the owner for the design–build project.

3.10 The Need for Specialized Training to Provide New Skills and Qualifications

Design–build projects have created a need for qualified and certified personnel working for all the stakeholders involved in the project. With the growing size and complexity of these projects, effective communication and documentation have become

extremely relevant. The need for specialized skills and qualifications has never been greater. The transportation design–build construction industry is moving toward increased use of technology, and the challenge remains to adequately train and certify all quality management professionals working on the increasingly complex design–build project. States have ramped up their personnel qualifications programs and require highly skilled quality management professionals as key personnel in the design–build team. The FHWA has set up stricter guidelines for auditing quality management programs. Design–build teams across the country are recognizing the need for a qualified and well-trained workforce.

3.11 The Need for System for Evaluating the Qualifications of the Design–Build Team and Its Approach Toward Quality Management in the Procurement Phase

Some state DOTs treat quality as a selection factor in shortlisting design–build teams and evaluating their proposals. Quality-related factors are separately rated and weighted as part of the selection and evaluation process. Other state DOTs do not explicitly rate quality-related factors as part of evaluating design–build teams and their proposals; however, this does not mean that the quality factors are not important in the selection of shortlisted teams and evaluation of design–build proposals. These state DOTs still review the qualifications of the quality management personnel and provide feedback for the proposed quality management plans. Nevertheless, a lack of unified approach to address quality issues can be a source of challenge for the transportation design–build industry.

3.12 Lack of Familiarity Regarding the Use of Contractor Samples in the Acceptance Procedure

The role of state DOTs in the quality management process of alternative delivery projects is transforming to oversight and independent assurance. State DOTs can utilize the samples taken by the design–builder for accepting the quality of the design–build project. However, state DOTs need to become familiar with a reliable verification and validation approach that can be rigorously implemented to ensure the results of the tests provided by the IQF are ready to be used in the acceptance decision. Understanding the principles of t-tests and F-tests (statistical approach toward the quality acceptance) is required for implementing a quality assurance program for the alternative delivery environment. Familiarity with the statistical analysis approach toward quality assurance may be challenging for some professionals in state DOTs and the transportation design–build industry.

CHAPTER 4. PRACTICAL COMPONENTS OF THE QUALITY ASSURANCE SYSTEM

4.1 Acceptance Approaches

The roles and responsibilities for various elements of the construction QA program significantly differ across states. Among QA programs, acceptance program is one of flexible activities that vary from state to state. The FHWA Techbrief (2012) states, “All acceptance activities must be carried out by the agency or their designated agent (i.e., consultant under direct contract with the agency) independent of the contractor. This does not preclude the inclusion of design-builder QC data, provided that the QC data are validated by the agency’s independently obtained verification data” (p. 4). If the state DOT establishes a dispute resolution system, 23 CFR 637 also allows quality control sampling and testing to be used in the acceptance program. In traditional DBB contracting, the responsibilities of quality control lie with the contractor, who has the duty to ensure that the project delivered complies with drawings and specifications. The responsibility of quality acceptance and oversight lies fully with the owner or the owner’s representative. In DB contracting, like DBB contracting, the responsibility of quality control lies with the design–builder (the contractor).

Two responses from the initial interview motivated the research to investigate the different approaches toward the acceptance decision. For example, historically, Colorado DOT’s approach toward acceptance on DB projects is that the design–builder is responsible for both QC and QA and CDOT is responsible for assessment of design, construction, and

IA. However, on the I-25 Ilex project, responsibility of QA had shifted to the DOT. The design-builder was only responsible for QC, similar to DBB projects, and CDOT performed QA and IA. The decision for the change in the practice was made based on past experience with DB projects. CDOT wanted to have more control and oversight of the work performed to handle non-compliant works in-house. The other example was related to MnDOT's current practice toward the acceptance practice. Ten years ago, MnDOT experimented with passing more responsibilities to the design-builder. However, currently, MnDOT still performs most of the material testing on their DB projects as in their DBB approach. The design-builder is only responsible for QC, and MnDOT is responsible for QA (not as comprehensively as in DBB, but they have 'Critical Activity Point' checks). On the Americans with Disabilities Act (ADA) trial project, MnDOT had a high-quality DB team on-board so that responsibilities for QC and QA lay with the design-builder, and MnDOT performed a minimal oversight role. MnDOT mentioned that they are open to different models as each may be appropriate.

4.1.1 Approaches for Quality Acceptance

The following subsections define three approaches for quality acceptance in a DB project based on levels of owner involvement in acceptance (see Figure 6).

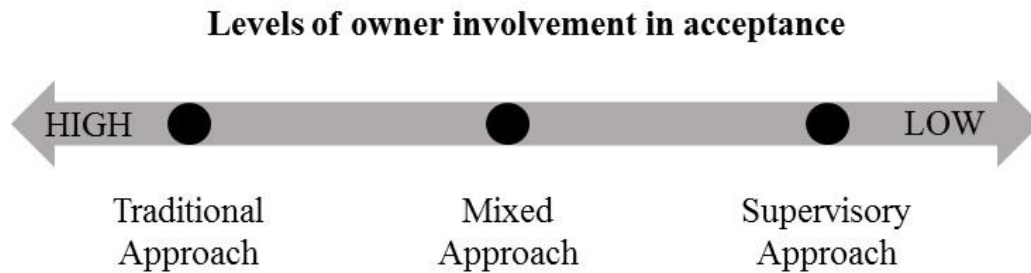


Figure 6 – Three acceptance approaches

4.1.1.1 Traditional Approach (similar to the DBB approach)

The traditional approach is similar to the acceptance approach in DBB projects. The design–builder is responsible for quality control, and the state DOT is responsible for all acceptance tasks. The state DOT or its consultant conducts all the verification sampling and testing. This approach typically is used by the Maryland, South Carolina, Montana, and Minnesota DOTs. For instance, the Colorado DOT (CDOT) traditionally allows design–builders to take the lead responsibility for quality assurance on its DB projects, but on the \$90M I-25 Ilex DB project, CDOT decided to retain the acceptance process completely in-house, similar to a previous case in which the CDOT used the DBB approach on a problematic DB project. The region transportation director for CDOT felt that the DOT would retain more control, and, in the end, have a well-organized project.

4.1.1.2 Mixed Approach (typical DB)

In a DB project, the design–builder is under contract to deliver a project complying with a quality standard specified in that contract. In this approach, the owner assumes an active role in carrying out acceptance duties on a daily basis. The owner may hire an

owner's verification firm to act on its behalf. Usually, the QC data of the design–builder and the testing data of the independent quality firm or contractor's quality assurance firm are taken into consideration in the acceptance process. The goal of the department is to ensure that the project is being constructed in accordance with contract requirements. This approach can be broken down to two levels of acceptance, as shown in **Error! Reference source not found.** The first line of acceptance is usually performed by the design–builder or a firm hired by the design–builder with the consent of the owner. This firm is referred to as an IQF or a CQAF. State DOTs usually have veto power when it comes to the hiring of these firms by the design–builder. The task of the IQF/CQAF is to perform inspection and oversight of on-site construction activities. To ensure that all work complies with the contract requirements, the IQF/CQAF performs regular sampling and testing.

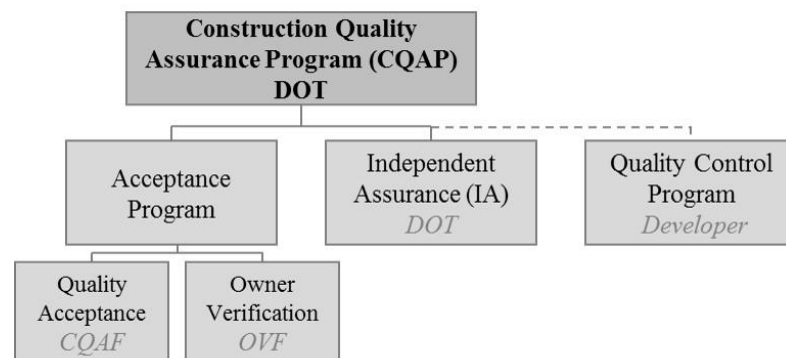


Figure 7 – Typical organizational chart of a DB project involving a mixed approach (Recreated from the GDOT Quality Assurance Plan)

After the first line of acceptance is performed by the IQF/CQAF, the owner-performed acceptance is implemented by the state DOT itself or a representative directly hired by the state DOT as the second line of acceptance. In large design–build projects, it is common that state DOTs hire an OVF, which provides the owner oversight, inspection,

and testing. Typically, the OVF performs random sampling and testing, done by the IQF/CQAF, at a 10% rate of frequency. The state DOT may choose to include the QC data of the design–builder and/or the test data of the IQF/CQAF regarding its acceptance decision. The mixed approach of acceptance is typical for several state DOTs: Colorado, Missouri, Texas, Georgia, Washington, Maine, Michigan, and Oregon. This research found that the Massachusetts and Utah DOTs are open to both traditional and mixed approaches to acceptance.

4.1.1.3 Supervisory Approach

The owner is not actively involved in day-to-day acceptance activities in the supervisory approach. The design–builder is primarily responsible for day-to-day acceptance activities, and the owner retains only minimal involvement in acceptance during a project. The liability may shift from the owner to the design–builder during the project; however, the owner cannot assign acceptance decisions to the design–builder. The typical acceptance approach of the Virginia DOT is probably most closely associated with the supervisory approach.

4.1.2 *Decision Factors*

The research found that DOTs differ when it comes to the selection of the method of acceptance for their projects (see Figure 8). 6 out of 17 DOTs—Colorado, Georgia, Maine, Missouri, Oregon, Texas, and Washington—use a mixed approach for their DB projects. Maryland, Minnesota, Montana, and South Carolina DOTs retain a traditional way, which is similar to DBB projects. Only Virginia DOT answered that their approach includes owner’s minimum involvement for acceptance program, which is described as a

supervisory approach. Some states such as Massachusetts and Utah prefer using two different approach, which are mixed and traditional approaches, on a project-by-project basis. Only Ohio DOT answers that they have experienced all three different approaches. The results, shown in Figure 9, also indicate that 10 out of 17 DOTs that responded to the email survey use a consistent acceptance decision approach, and the other seven DOTs—Colorado, Missouri, Minnesota, Utah, Ohio, Massachusetts, and Maryland—are open to change their acceptance decision approaches project by project.

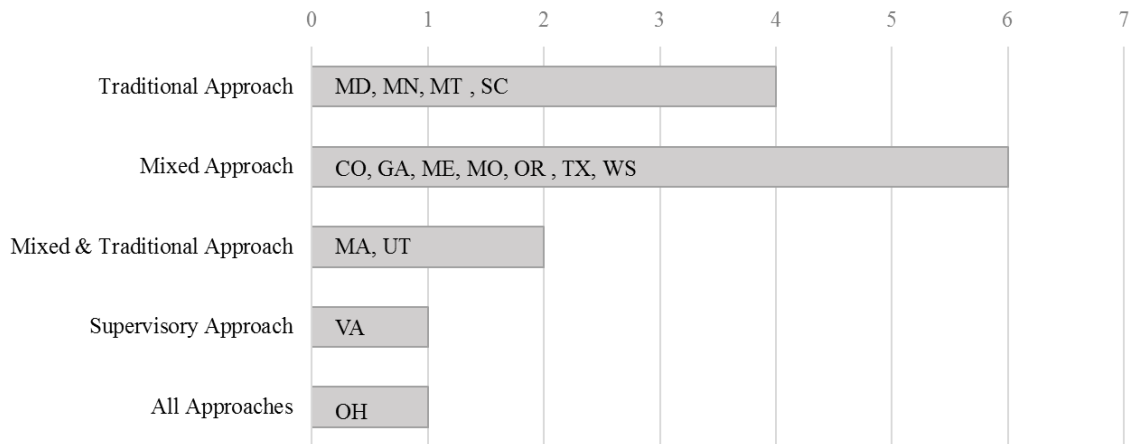


Figure 8 – Distribution of state DOTs based on their acceptance approaches

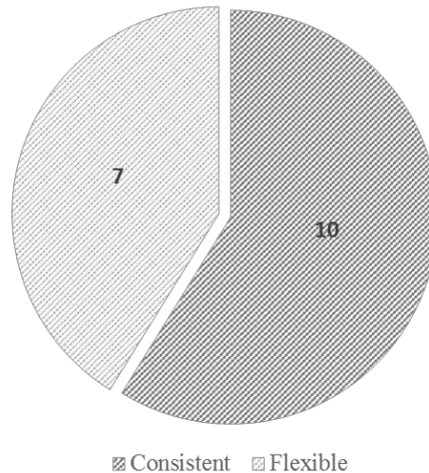


Figure 9 – Consistency of acceptance approaches

Figure 10 shows the identified main factors that play a role in this decision:

- Past experience with similar projects
- Capability and experience of the IQF, and the extent to which a DOT can rely on and trust the IQF
- Size of the project at hand
- Motivation to save on the project cost and schedule
- Unique requirements such as the constructability and the complexity of the project
- Current availability and expertise of in-house QA personnel
- Involvement in the operations and maintenance (O&M) component of the project

Most DOTs determine acceptance approaches based on specific risk areas of a project, the history of performance, and the credibility of the design–builder on board. If the QC activities of the design–builder are lacking, the DOT increases its level of review

and inspection. When the DOTs that using the typical approach have not enough resources to provide quality management, they tend to include the design–builder in the acceptance process. Current availability and expertise of in-house QA personnel are also important factors. The Missouri DOTs follows the mixed approach for acceptance, but they decided to use in-house inspection personnel because of the availability of qualified inspectors throughout different parts of the state, which led to cost savings. On larger projects, while the design–builder performs both quality control and acceptance, The Missouri DOT retains only the responsibility of quality verification. The UDOT also decides whether to use an IQF or perform QA in-house based on factors such as project size and in-house resource availability. The Texas DOT also uses the mixed approach for the acceptance program that includes tests by the DB firm with validation from the department. The main reason for Texas DOT’s decision is project schedule. Texas DOT does not want to slow down the contractor or affect the contractor’s schedule. Considering its limited resources, Texas DOT believes it cannot keep up with the pace of construction if it decides to perform all the acceptance tests.

Ohio DOT have implemented all three acceptance approaches. For their major DB projects, procured with low-bid, they use in house acceptance and verification. However, on large DB projects, which accrued project costs of more than \$200 million, Ohio DOT adopted a mixed approach for acceptance. An IQF conducted both design and construction quality management tasks. Based on the experience of the Ohio DOT, the IQF worked more effectively in the design role than in the construction role, but the Ohio DOT had to hire the IQF for construction due to limited staffing resources. However, on a design–build–finance–operate–maintain (DBFOM) project that the Ohio DOT was working on at

that time, which required the developer to maintain the project for 35 years, the department adopted the supervisory approach. Since the risk of the Ohio DOT on this type of project was lower than that of typical DB projects because of the long-term contract, the Ohio DOT felt that spending heavily on quality assurance was not efficient.

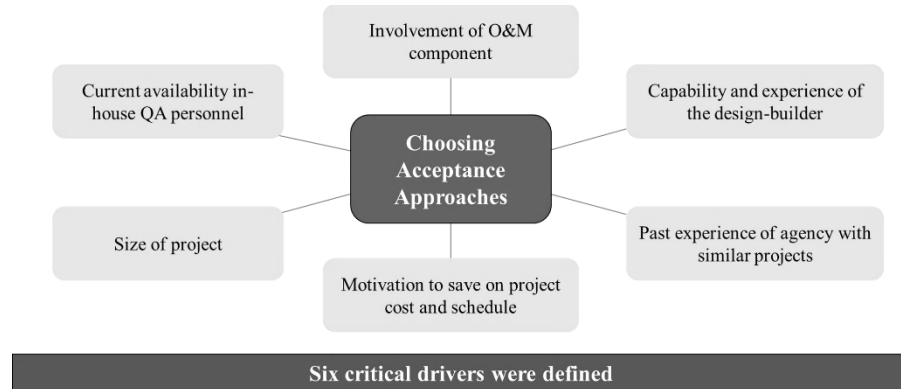


Figure 10 – Decision factors of acceptance approaches

4.2 Selection Criteria

This section explores the importance placed on quality assurance management at the procurement/selection phase of the design–build team. Typically, the selection of a DB team comprises a two-step process, a qualifications phase and then a proposal evaluation phase. Through the structured interview process, 12 state DOTs that replied to the survey regarding the emphasis the states put on quality assurance during RFQ and RFPs phases.

4.2.1 RFQ Phase

Error! Reference source not found. shows the consideration for quality assurance in the RFQ phase among state DOTs. Nine out of 12 states consider quality as a selection parameter. The figure illustrates the position of different states on various other factors. Although only two DOTs consider past experience in the quality management plan, 9 of 12 DOTs deem the quality manager as key personnel. The overall quality management approach of the design–builder is also a part of the evaluation criteria, and half of the respondents evaluate the design–builder’s approach toward the quality management. Complying with the six core elements of QA, some DOTs also consider the inspector, technician, and testing lab accreditation as selection criteria.

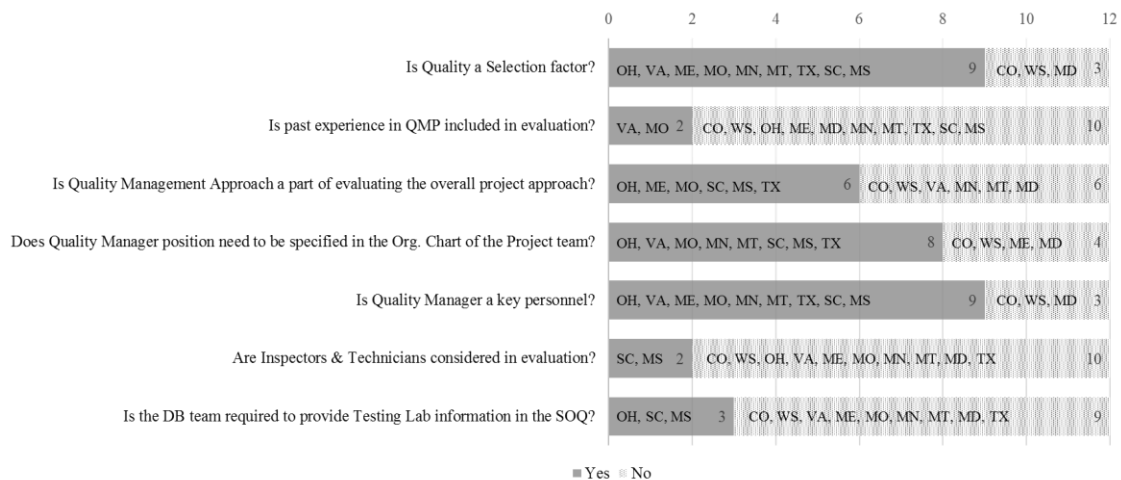


Figure 11 – Shortlisting criteria in RFQ phase

4.2.2 RFP Phase

Figure 12 shows the consideration of quality assurance in the RFP phase among state DOTs. Ten out of 12 states consider quality as selection criteria in the proposal phase.

Colorado and Minnesota DOTs do not place quality as a selection parameter during either the RFQ or RFP phases, while other state DOTs place a strong emphasis on quality for their design–builder selection process. Four DOTs still require the design–builder to submit the statement of qualification (SOQ) in the RFP, which is already evaluated in the RFQ phase. The figure also illustrates other quality-related issues, such as whether the QMP is considered a part of the technical proposal. Five out of 12 DOTs responded that they evaluate the design–builder’s QMP. Half of the respondents indicated that the detailed QMP is required to be submitted after award. Although the QMP is not a part of their evaluation in the RFP phase, some DOTs require the design–builders to submit the detailed QMP if the projects are awarded.

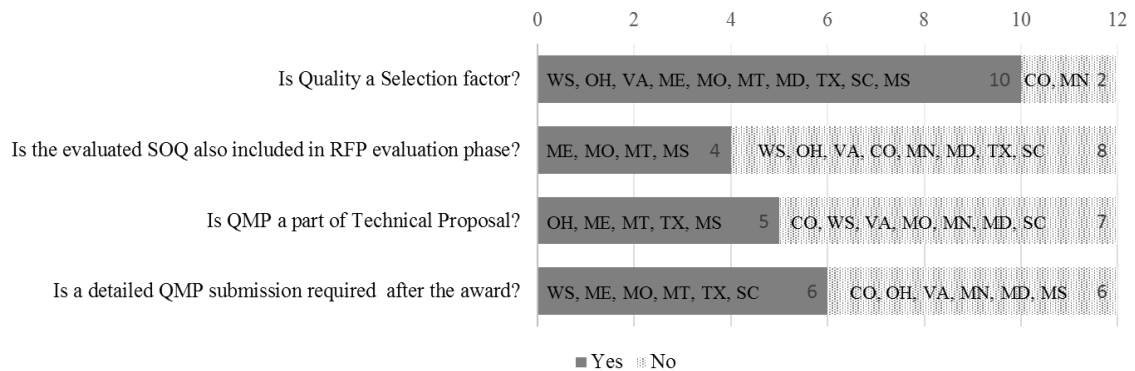


Figure 12 – Proposal evaluation in RFP phase

4.2.3 Quality Management Plan

According to the responses to the initial interview, one of the significant differences between DBB and DB projects is that some DOTs required the design–builders to submit their own QMPs. Follow-up emails were sent to the interviewees to investigate the

development of the QMP. The QMP is not evaluated during the RFP process by MnDOT, SCDOT, or WSDOT. However, those DOTs required submission of the detailed QMP after award. In the evaluation, the Ohio DOT would score and rate the identified strengths and weakness of the draft quality management plan and overall quality approach as compared to the requirements of the scope of work. Based on the follow-up emailed interviews and reviews of the RFPs, in general, design-builders need to submit the final (or first draft) QMP after award, usually within 15 to 30 calendar days of a notice to proceed (NTP). No construction work may be started without the approval of the department. The following detailed responses are reported by state DOTs regarding the timing of submitting the NTP for review and approval.

- Ohio DOT mentioned that the selected firm will submit the initial QMP within 15 business days for the department to approve or reject. For subsequent revisions to the QMP, the department requires 10 business days to approve or reject the submission.
- Missouri DOT also allows 15 business days after the NTP, but the department requires the final written design and construction QMP.
- MnDOT requires the design-builder to submit the quality manual for MnDOT's approval as a condition of its Notice to Proceed 2 (NTP2) and will respond within 20 working days of receipt of the quality manual.
- WSDOT requires the design-builder to submit a draft QMP within 30 calendar days of NTP.

Some state DOTs provide a QMP that can be used as a template to assist the design-build team to develop its own QMP for the project. However, some DOTs, such as

Michigan DOT, do not have their own quality manual to provide to the design–builder. The QMP submitted by the design–builder is expected to meet the minimum requirements as outlined in the state DOT’s QMP template or contract documents. For instance, MnDOT has developed a QM Template to aid the design–builder with development of the QM for the project. These documents may not include all processes and procedures required for the project. The department allows modification and enhancement of these documents as necessary to provide an overall comprehensive quality manual for the project. The contractor may provide a QM developed independently, but it must cover all the topics contained in MnDOT’s Quality Manual Template and meet all requirements of the contract. WSDOT also provides a “Quality Management Plan Outline.” The design–builder may either use all or part of the QMP Outline or make changes to meet their own quality approach. On the other hand, Ohio DOT does not provide a quality management manual, so the design–builder needs to develop, implement, and maintain a quality management program covering all elements of the project, including management, administration, design, geotechnical investigations, construction, testing, environmental monitoring, and compliance.

If the QMP is not in compliance with DOT requirements, the QMP can be modified and enhanced by the state DOT or the design–builder as needed throughout the project. If a systematic problem is found regarding compliance with the Department’s specifications and materials manual, the state DOTs may participate in the development and modification of the QMP. The Missouri DOT mentioned that the submitted QMP (the sampling, testing, and reporting of all materials) may be modified when it is not in compliance with the Missouri DOT Specifications and Materials Manual. The MnDOT agrees that the quality

manual and its implementation can be revised when either the contractor or the MnDOT identifies a systemic problem. The Ohio DOT requires the design–builder to coordinate and engage the department in the QMP development to facilitate approval and ensure understanding of requirements. In addition, the Ohio DOT indicated that participating or providing inputs does not waive the responsibility of the design–build team for meeting the expected quality of the work, nor does it ascribe any responsibility to the department for the work. Further, this involvement does not preclude subsequent rejection of the QMP by the department.

4.3 Independent Assurance

The independent assurance program provides an independent verification of the reliability of all data used by the DOT in the acceptance determination. IA ensures that the sampling and testing activities performed by the DOT and the design–builder are conducted by qualified personnel using proper procedures and properly calibrated and functioning equipment (FHWA 2012). In 23 CFR 637, it states that “[e]ach IA program shall include a schedule of frequency for IA evaluation. The schedule may be established based on either a project basis or a system basis. The frequency can be based on either a unit of production or on a unit of time.” The DOT is responsible for IA that is usually conducted by the DOT itself or a designated agent directly contracted by the department.

The FHWA Techbrief (2012) also suggested that “For agencies that do not routinely include QC test results in the acceptance determination, using this approach on DB projects may create new challenges for the IA system. The design–builder may not be familiar with

IA requirements. The need for the design–builder QC staff to cooperate with IA personnel should be clearly stated in the DB contract.” Per 23 CFR 637.209, “all personnel performing sampling and testing for QC used in the acceptance decision, verification, or IA are required to be qualified. And laboratories operated by a designated agent of the agency that are used for IA or dispute resolution must be accredited by AASHTO, through a comparable program approved by the FHWA, or by an accreditation body approved by the National Cooperation for Laboratory Accreditation.” The FHWA (2011) defines three IA procedures, as discussed in the subsections below.

4.3.1 Project Approach

This IA procedure is the traditional approach in which the frequency of IA testing and sampling is set up on a project basis. In general, the DOTs use a frequency of 10 percent of the verification and acceptance testing.

4.3.2 System Approach

An alternative approach to deciding IA testing frequency is doing it on a time basis for all testers and equipment. The general idea is to proctor all the testers and equipment over a period of a year. The purpose is to cover all the testers and equipment over that year-long period. This approach can help ensure that most testers are reviewed and the same testers are not reviewed continually.

4.3.3 Mixed Approach

It is permissible to separate the verification of equipment and personnel. The underlying consideration to this approach is that some tasks are better suited to the project approach and should be easily reviewed based on a certain fixed frequency rate, no matter the tester or the testing equipment. Other tasks are more dependent on the equipment quality and the personnel capability. These tasks should be reviewed based on a system approach. Together, this is called the mixed approach. One method that check testing equipment is to require a calibration and inspection frequency. Testing personnel can be checked by sending out proficiency samples. Some test procedures and or some testers are covered by a project approach where the remaining procedures are covered by a system approach.

4.3.4 Summary of the Interview Findings about the State of the Practice in IA Approaches

Initial interview related to IA procedures was targeted to ten state DOTs. Half of the respondents—Colorado, Maryland, Montana, South Carolina, and Washington DOTs—use project approach (see Figure 13). Three of ten such as Texas, Maine, and Missouri DOTs answered that they use the system approach. Only Oregon DOT mentioned that their approach is similar to the mixed approach. MnDOT does not implement a separate IA function since it performs QA services in-house and finds this approach more cost and time efficient. MnDOT no longer hands over the QA material testing on most of their DB projects. “MnDOT does not have large and national DB firms bidding on most of our projects (to lead the way into this) and the local industry has had troubles converting.” Therefore, “for materials specifically, MnDOT is doing QA and not IA.”

Among ten DOT, except Minnesota and Oregon, eight DOTs use a consistent IA approach (see Figure 14) throughout their design–build programs. Eight DOTs out of 10 answered that their approach does not change based on project types. WSDOT only changes the IA approach from project to project based on the number of non-conforming issues (NCIs) reported. SCDOT mentioned that if there are issues on a particular project, then the Office of Materials and Research (Central Lab) will visit the project and study the issue in depth with on-site staff. Maryland DOT generally follows the same approach on all projects; however, it could change for a specific project needs. Only one DOT mentioned that its approach to IA is similar to the mixed approach. Oregon DOT feels the traditional per-project basis provides more efficient oversight and control of project construction. Not all technicians in the certification program are evaluated, but only those individuals directly involved with the project. Oregon DOT’s IA program is mostly based on a quantity-per-project frequency that is similar to a project approach. Test results are then analyzed according to QA program language and project criteria. At the same time, Oregon DOT uses a system approach for the technician certification program, though based on a 5-year period versus annual evaluations. Also, the lab certification process uses a system approach based on an annual evaluation. Therefore, both systems are utilized but with a different application.

Several reasons are identified by state DOTs in deciding the most appropriate IA approach for the design–build environment as summarized below. For instance, WSDOT uses the project approach because this approach is to stay at the QV (quality verification) level on all projects, while at the same time utilizing available resources effectively. CDOT selected this method for the ease of coordination with their regional lab (essentially the

same as a design–bid–build). On the other hand, Missouri DOT switched to the system approach several years ago since the former project-based approach simply conducted the test for every specified volume of material on a project. It was found that Missouri DOT would perform duplicate tests of the materials. Under the current system-wide approach, Missouri DOT proctors the testers to ensure they are using proper procedures in sampling and testing, and the same testers are not repeatedly proctored. The IA program of TxDOT is established using the system approach based on the evaluation of the qualified sampling and testing personnel and testing equipment. The merit of the system approach is efficiency balanced against quality of personnel and equipment because this approach bases frequency of IA activities on time, regardless of the number of tests, quantities of materials, or numbers of projects tested by the individual being evaluated.

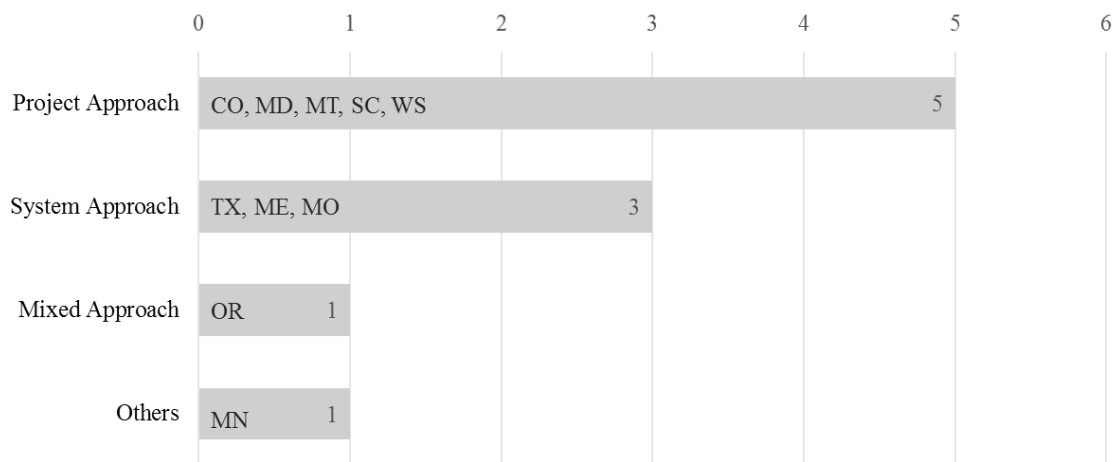


Figure 13 - Distribution of state DOTs based on their IA approaches

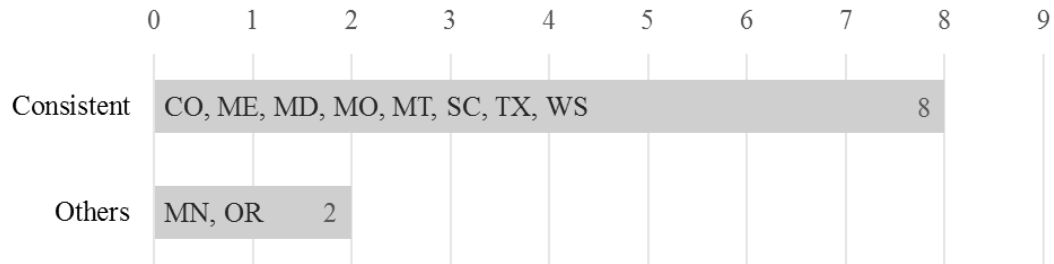


Figure 14 - Consistency of IA approach

4.4 Non-Conformance Reports (NCRs)

Per 23 CFR 637, DOTs that include QC testing data in the acceptance determination are required to have dispute resolution system to resolve possible discrepancies between the design-builder's QC data and the agency's acceptance data (FHWA 2012). NCRs are one of elements consisting dispute resolution system. Regarding the question, "Does FHWA recommend a process for non-conforming materials and workmanship or are the DOTs free to decide their own process?", the FHWA answered that the ultimate resolution to the NCR should be documented, and the owner (or agency) should retain oversight/approval authority of that resolution. NCR contains details of the work that is non-conforming. Elements of NCR include the observed reason for the non-conformance and detailed remedial actions proposed to achieve conformance to the contract requirements. Non-conforming product shall be reviewed in accordance with documented procedures and one of the following decisions must be made about the NCR element: (a) reworked to meet the specified requirements, (b) reworked in accordance with a department-approved rework procedure, (c) regarded for alternative applications, or (d) rejected or scrapped. Figure 15 shows the flowchart of an example NCR process currently

practiced by the Arizona DOT (ADOT). When the results of the OV test do not statistically meet the test results of quality acceptance, ADOT and the IQF jointly investigate the non-conformance. In addition to the need to validate the non-conformance, the material in question needs to be assessed to determine if the material can be left in place or has to be removed, reworked, or repaired. If the material in question is to remain, this material needs to be evaluated using the process provided in the QMP. Engineering judgment can be used to determine whether the material will perform its intended purpose (Arizona Department of Transportation 2016).

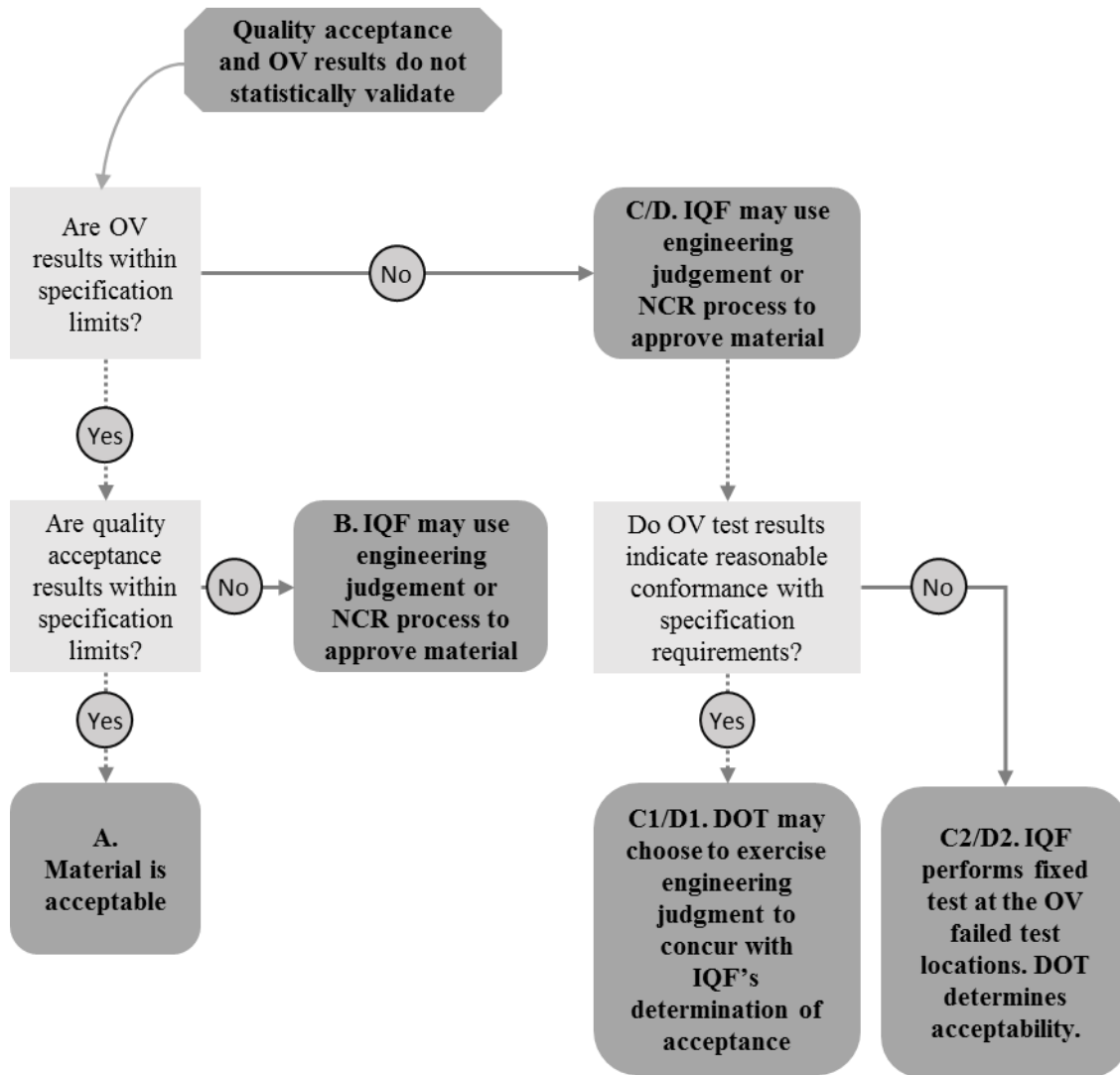


Figure 15 - Non-validation flowchart (Recreated from Arizona Department of Transportation 2016)

4.4.1 Summary of the Interview about the State of the Practice in the NCR Process

Figure 16 shows that 6 out of 11 DOTs implement NCR procedures. NCR is only used if there is an IQF working for the contractors and the contractor's tests are used for acceptance and as the basis of payment. Four DOTs such as Maine, Maryland, Ohio, and

South Carolina DOTs do not use QC data in acceptance determination so that they do not use NCRs procedure. In addition to these four DOTs, the Arizona DOT commented that they do not use NCRs on DB projects, but only on P3 projects. DOTs, which are implementing NCR procedures, expect the quality assurance manager, who is an employee of the IQF and handles non-conformance, to issue most NCRs. The QAM will be responsible for obtaining resolution to NCRs. If the IQF fails to issue the NCR, the state DOT still can do it. DOTs have reported that contractors will go to great lengths to avoid receiving an NCR because they do not want those on their records, which may possibly be used for future consideration in shortlisting and proposal valuation. It is important for state DOTs to educate design-builders about the NCR process and assure them that it is aimed to streamline the method of resolving quality issues for the project.

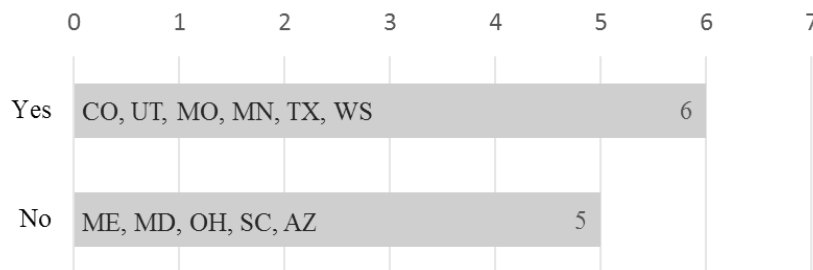


Figure 16 - Implementation of NCRs

4.5 Cost Mechanism

Budgeting and funding QA in a DB project is a key factor to ensure that sufficient resources are available to conduct all the QA tasks as required by the project. To get an

insight into the key factors that influenced the decision-making for the choice of a funding mechanism for QA, the following three-part question related to cost mechanism was sent:

- What is your mechanism for budgeting QA services in design–build projects?
- Is the QA budget based on a set percentage (like 3%–4%) of total project cost?
- Or is it broken down based on different types of tasks that need to be performed as part of QA services?

4.5.1 Summary of the Interview Findings about Cost Mechanism for Quality Management Tasks in the Design–build Environment

In response to the first question, three approaches of QA funding mechanisms are identified. Figure 17 show that 7 out of 11 DOTs answered that QA budget is based on a percentage of the design–build contract, approximately 3% to 4%. Table 1 elaborates detailed cost mechanisms applying to DOTs. Missouri and South Carolina DOTs mentioned that they develop the QA cost estimate based on the tasks required for the project quality. Oregon and Colorado DOTs do not budget quality-related cost separately; instead, they include it in the overall project budget.

The second question the survey asked the state DOTs regarding the budgeting issue for quality tasks. All DOTs answered that they do not require a certain ‘X’ amount or ‘X’ percentage toward quality management if the design–builder achieves quality requirements in accordance with the QMP developed for the project. The general trend observed was that the DOTs are more concerned that the design–builder allocates sufficient resources to ensure that the required tasks are conducted properly. Missouri DOT reported that it may

be desirable to make sure that the design–builder spends a certain ‘X’ amount or percentage in future projects.

For the final two-part question related to budgeting and cost management for quality tasks, most DOTs are concerned with the performance. As long as performance is ensured, they are not too concerned about how quality is achieved. However, one common trend among DOTs is not observed here, as the DOTs provided varied answers to this question. TxDOT and Maine DOTs make sure that the correct number of tests are done and the inspection level meets the specifications of the contract. Ohio DOT and SCDOT verify this by the performance.

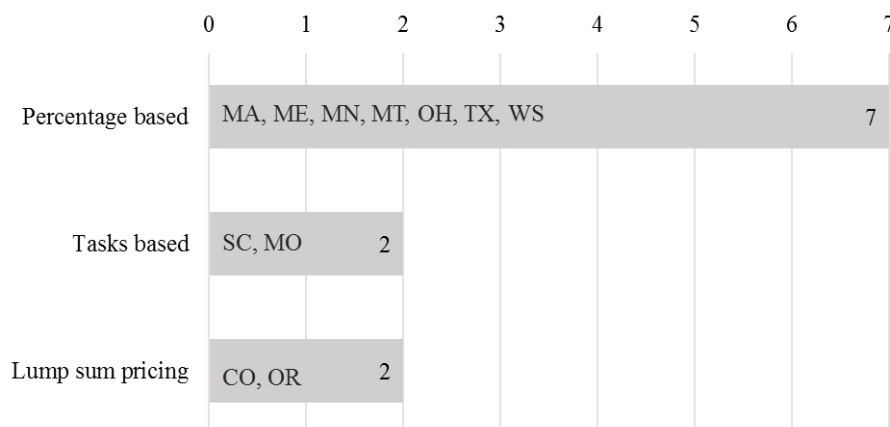


Figure 17 – Mechanism for budgeting QA services in design–build projects

Table 1 – States with Percentage-based Mechanism for Budgeting QA Services in Design–Build Projects

State DOT	Approximate Percentage of Project Cost Spent on Quality
	Assurance
Maine DOT	3% of the project cost
MnDOT	Usually 3–4% of the project cost. Historically about 3.3%, recently 3.8%
WSDOT	6% +/- for the design–builder to provide QA/QC, 14% for WSDOT to perform quality verification and independent verification
Montana DOT	QA services within CE costs which is at 10%
TxDOT	3% for quality assurance and 0.75% for IA
Ohio DOT	4% of total cost

4.6 Pay Factors

The FHWA recommends implementing pay factor adjustments for DB projects. In principle, the adjustment should not be different between lump-sum DB projects and unit-price DBB projects. Since a DB project can be thought of as a compressed DBB project, the lump-sum items still need to be sampled and tested according to the material requirements of 23 CFR 637 in all FHWA federally funded projects. The DOT’s proposed pay factor strategy is required to be approved by their local FHWA Division Office.

4.6.1 Summary of the Interview Findings about Pay Factor Adjustment

Figure 18 shows that 8 DOTs out of 11 implement pay factors for design–build projects. State DOTs track schedule of values and installed quantities, submitted by the design–builder, to calculate the adjustment amount. There are two approaches to determine the unit price of the line items subject to pay-factors adjustment. The design–builder is required to provide unit costs for the hot mix asphalt (HMA) items as part of the

establishment of their work breakdown structure. Another approach is that DOTs insert special provisions identifying the unit price to calculate incentives/penalties. Several state DOTs apply pay factor adjustments using a change order process. In traditional design–bid–build projects, several state DOTs adjust payment for line items based on the levels of quality criteria, e.g., asphalt pavement and concrete structure line items. With DB projects, most DOTs still implement pay factors on DB projects for either Portland concrete cement pavement (PCCP) or HMA, or both. Table 2 represents line items for pay factors that are used by the eight DOTs. Two of those eight DOTs applied pay factors for PCCP only, and another two DOTs only applied pay factors for HMA. The remaining four DOTs implemented pay factors for both PCCP and HMA.

Most DOTs emphasize the quality achievement for PCCP and HMA, and pay factors are applied based on the results of material testing. Table 3 represents specified types of material testing that are applied pay factors, as provided by respondents. Three of six DOTs that implement pay factors for PCCP consider concrete thickness as a critical factor. Concrete strength, concrete smoothness, and concrete air void are also material tests applied pay factors. With HMA, asphalt binder and pavement thinness are weighted to adjust payment based on the levels of quality achievement by four of six DOTs. Maryland and Utah DOTs provided elaborate items of pay factors, which also consider pavement marking paint.

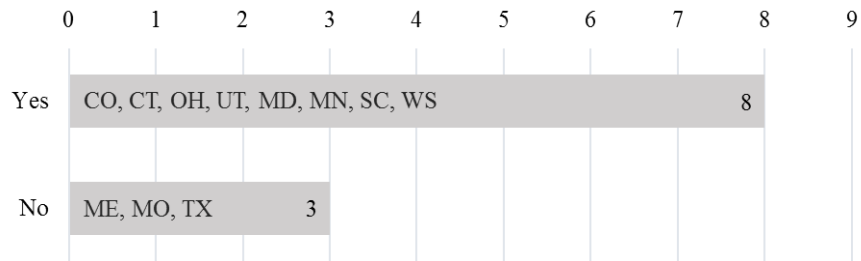


Figure 18 - Implementation of pay factors

Table 2 – Line Items for Pay Factors

State DOT	Portland Concrete Cement Pavement	Hot Mix Asphalt
Arizona DOT	Yes	No*
Maryland DOT	No*	Yes
MnDOT	Yes	No*
Ohio DOT	No*	Yes
SCDOT	Yes	Yes
CDOT	Yes	Yes
CTDOT	Yes	Yes
UDOT	Yes	Yes

No*: Email answers and/or RFPs do not indicate pay factors.

Table 3 – Material Tests for Pay Factor

Line Items	Types of material testing	AZ DOT	Maryland DOT	Mn DOT	Ohio DOT	SC DOT	CDO T	CT DOT	Utah DOT
Portland Concrete Cement Pavement (PCCP)	Concrete strength	Yes							Yes
	Concrete thickness	Yes						Yes	Yes
	Concrete smoothness	Yes		Yes					
	Concrete air void content			Yes				Yes	
Hot Mix Asphalt (HMA)	Aggregate base					Yes	Yes		
	Asphalt binder		Yes		Yes			Yes	Yes
	Asphalt mixture		Yes						
	Pavement density		Yes		Yes			Yes	Yes
	Pavement surface profile adjustment		Yes						
Others	Pavement marking paint		Yes						Yes

CHAPTER 5. **DISCUSSION**

In the last few decades, the methods and procedures relating to quality assurance management have undergone several changes with the introduction of alternative delivery such as DB in transportation projects. In addition, state DOTs have limited resources for keeping up with the demand of large-scale DB projects, which has led to a loss of direct control over agencies' day-to-day quality activities. These changes results in different practices regarding the roles and responsibilities for various elements of the construction QA program across states. The newer methods such as DB expand the contractor's role in construction quality management by including several QA tasks that traditionally performed by DOT personnel. To clarify the roles and responsibilities regarding quality assurance program for alternative delivery projects and comply with 23 CFR 637 and the FHWA's Techbrief (2012), a comprehensive construction quality assurance program should consist of six core elements: (1) QC, (2) acceptance, (3) independent assurance, (4) dispute resolution, (5) personnel qualification, and (6) laboratory accreditation/qualification.

Use of alternative delivery methods does not diminish the need to perform any of these QA functions; however, the party performing them may differ from the DOT's standard practices. This study examined different practices in QA core elements across all DOTs that are actively using DB projects and cost-related components such as QA funding mechanisms and pay factors. While the process of QC is similar across the DOTs, this study found that the other five elements of QA core elements and cost-related components vary from state to state. Some DOTs use a consistent approach to quality assurance

management, and other DOTs tend to change their approach depending on the project size, staff availability, agency experience, and so forth.

Acceptance activity is one of the flexible activities among QA core elements. This flexibility is mainly due to a use of design-builder testing data and the involvement of the third party such as an IQF and a CQAF. Although the responsibility of quality acceptance and oversight totally lies with the owner or the owner's representative, this allows the owner to retain only minimal involvement in acceptance during a project. Based on the degree of owner's involvement during a project, acceptance activity can be categorized into three group: (1) traditional, (2) mixed, and (3) supervisory approaches. Although the project is delivered with design-build method, some DOTs still use traditional DBB way (traditional approach). They feel that the DOT would need to retain more control and, if not, the project does not go well as planned. On the other hand, other DOTs mentioned that traditional approach is just duplication of the work already done by the design-builder so that they choose mixed approach. The Ohio DOT elaborate their practices and the reasons why they chose different approach depending on projects. If the project is small, it would be easier for DOT to handle all quality activities at their hands. However, if the risk of DOTs becomes lower when involving operation, maintenance, and financing components, DOTs would want to shift more liabilities to design-builder. Existing study, conducted by Kraft and Molenaar (2015), discovered 10 selection factors of quality assurance organization. Those 10 selection factors are similar to the decision factors of acceptance approaches that this study discovered, but previous study covered all types of project delivery methods. Thus, this previous study did not focus on the involvement of an IQF (or a CQAF), which is the new roles and challenges that DOTs have. In addition to those 10

selection factors identified by Kraft and Molenaar (2015), this study discover that DOTs tend to change and decide their acceptance approaches based on capability and experience of the IQF, the extent to which a DOT can rely on and trust the IQF, and involvement in the operations and maintenance (O&M) component of the project by conducting interview of 17 representatives from each DOT.

Moving on to selection criteria, this section covers personnel qualification and laboratory accreditation among six QA core elements. This explores the selection phase of the design-builder considering how DOTs evaluate quality management. The RFQ phase requires design-builder to involve the qualified personnel and accredited laboratory in a project. Most DOTs consider a quality manager as key personnel and require several years of experience and relevant certification. Although only two DOTs evaluate accredited laboratory during selection phase, most DOTs require design-builders to include accredited laboratory as stated in contract documents. The RFP phase focuses on evaluating quality management plans (QMPs) because state DOTs have different approaches when it comes to guidebooks and quality management manuals for projects delivered under alternative delivery. Some state DOTs have developed quality management manuals that design-builders are required to follow. This serves as a minimum requirement on all their design-build projects for quality management purposes. Other states tend toward a different approach in which the state DOT requests the design-build team to propose a quality assurance plan for the design-build project and the state DOT evaluates the plan during the selection phase. The transportation design-build industry is facing a challenge in handling different quality management expectations while working with different DOTs across the nation.

Independent assurance (IA) is to assure all testing and samplings complying with contract documents. The FHWA suggested two different ways to conduct IA. DOTs choose IA approach depending on the needs and conditions of their practices. DOTs with project approach mentioned that they want to follow the same frequencies (10%) for all projects and do not want to change their testing frequencies project by project. This approach is also easy to coordinate with their regional lab. On the other hand, DOTs that switched to system approach from a formerly used project approach commented that the former project approach simply computed that for every specified volume of material on a project. In this way, they feel that we would perform duplicate tests of the materials. Under the current system approach, however, they proctor the testers to insure they are using proper procedures in sampling and testing and the same testers are not repeatedly proctored. The FHWA also allows DOTs to use two IA approaches at the same time, which is named the mixed approach. One of DOTs explained that their IA program is mostly based on a quantity-per-project frequency that is similar to a project approach. At the same time, they use a system approach for the technician certification program though based on a 5-year period versus annual evaluations. Also, the lab certification process uses a system approach based on an annual evaluation. To find efficient way, they utilize both systems but a different application.

As a part of dispute resolution system, non-conformance process is required when an IQF is working for the contractors and the contractor's tests are used for acceptance. This process is to resolve the discrepancies between design-builder's testing data and agency's acceptance testing data. These DOTs that involve contractor testing data prefer the contractor to be responsible for quality. They will do audits on the quality staff and inspect

the work to ensure they are checking the right items and issuing NCR's if necessary. If Dots do not use QC data in acceptance determination, they do not need to use NCRs procedure. Although these DOTs do not require formal NCRs, any failing tests or deficient work must be documented and brought to the attention of DOTs. DOTs will also notify design-builders of any deficient items discovered through DOT testing or inspection. One of issues regarding NCRs is that contractors want to avoid receiving an NCR because they do not want those on their records, which may possibly be used for future consideration in shortlisting and proposal valuation. Thus, it is important for state DOTs to educate design-builders about the NCR process and assure them that it is aimed to streamline the method of resolving quality issues for the project.

Budgeting and funding QA in DB projects are key factors to ensure that sufficient resources are available to conduct all the QA tasks as required by the project. Since DB project is contracted with lump-sum pricing, it is difficult to track and confirm the amount of money spent on each line item. Interview related to QA funding revealed three different approaches that DOTs are using to distribute their budgets. Most DOTs budget and estimate QA services by percentage. It is usually three to four percent of the project cost. Although this amount varies a bit by project size and type, the percentage is fairly stable across the DOTs. This percentage is based on an analysis of the required tasks to be performed for the project. Budgeting for QA services also can be based on work breakdown structure (WBS), and DOTs ensure that design-builders have adequate resources budgeted for QA before approving the final schedule and WBS. Since the QA is lumped in with our overall construction engineering costs, some DOTs do not budget separately. They just include QA services in the project lump-sum pricing. DOTs also do not require a certain

‘X’ amount or ‘X’ percentage toward quality management. The general trend observed was that the DOTs are more concerned that the design–builder allocates sufficient resources to ensure that the required tasks are conducted properly. It may be desirable to make sure that the design–builder spends a certain ‘X’ amount or percentage in future projects.

The FHWA recommend DOTs to apply pay factors in their DB projects. Pay factor adjustment should not be different between lump-sum DB projects and unit-price DBB projects. Since a DB project can be thought of as a compressed DBB project, the lump-sum items still need to be sampled and tested according to the material requirements of 23 CFR 637 in all federally funded projects. There are mainly two approaches to determine the unit price of the line items subject to pay-factors adjustment. The design–builder is required to provide unit costs for the hot mix asphalt (HMA) and Portland concrete cement pavement (PCCP) items as part of the establishment of their WBS. The quantities are tracked and the adjustments would be made just like DBB projects. Another approach is that DOTs insert special provisions identifying the unit price to calculate incentives/penalties. Several state DOTs apply pay factor adjustments using a change order process. They keep track of those adjustments that are non-conforming to the contract requirements and that are not approved by the contractor engineer-of-record. Although DOTs are using different ways to assign pay factors in their DB project, most DOTs mentioned that they use the same processes for DBB and DB projects.

There is not a single project that can be done under the same conditions as the previous work. That is why the successful and well-developed practice for one project is difficult to apply for another project in the same way. Thus, quality assurance practices vary from state to state and project by project. As one of essential area of project success,

quality management is extremely important for construction projects in general, and its evolution and state-of-the-art trends are vital to be explored and considered for highway construction projects to be successful as things progress. DOTs have experienced and learned from their quality management practices, and they revise and update their practices if their approach did not work well. Therefore, these state-of-the-art practices from DOTs will be helpful to understand why some DOTs choose their quality assurance approach over other approaches that other DOTs are using.

CHAPTER 6. CONCLUSIONS

Based on the findings of the interview and content analysis of the documents provided by the state DOTs, this study concludes that implementation of an efficient and effective quality management plan represents a set of new challenges for state DOTs in the alternate delivery environment, as follows:

- Reluctance of state DOTs to shift the responsibility of quality assurance (QA) to the design–build team
- Reluctance of contractor to accept the new role of QA in the DB environment
- Developing an appropriate quality management for the alternative delivery when detailed design and actual quantities are not available
- Developing an adequate and reliable budget for quality management tasks and conducting cost control
- Differences in terminology used by each state DOT for quality management
- Lack of a unified and consistent guidebook for quality management across all state DOTs
- Differences in organizational structure of DOTs for quality management
- Understanding new roles and responsibilities in design–build projects
- The need for specialized training to provide new skills and qualifications
- The need for a system for evaluating the qualifications of the design–build team and its approach toward quality management in the procurement phase
- Lack of familiarity regarding the use contractor samples in the acceptance procedure

It is important to examine practical components of QA system. QA core elements, suggested by the FHWA, consist of QA system and these elements represent real-time issues that DOTs have experienced and concerned. This exploratory study shows the implementation of quality assurance system from different state DOTs that are actively using DOTs. DOTs have different approaches toward their own quality management. This study also identifies key factors that influence the selection of different approaches by conducting interview of state DOT personnel and a content analysis. This study covers practical components of QA system, as follows:

- Acceptance approaches and decision factors to choose the most appropriate acceptance approach for the design–build project
- Selection criteria and quality management plan
- Independent assurance methods (i.e., project approach, system approach, and mixed approach)
- Non-conforming reports (NCRs)
- Budgeting and cost control for quality management tasks in the design–build environment
- Pay factor adjustment for quality in the design–build environment

In summary, several new areas have arisen as a result of the growing number of projects delivered by design–build and other alternative delivery systems. The specific area of quality management is extremely important to construction projects in general, and its evolution and state-of-the-art trends are vital to be explored and considered for highway construction projects to be successful as things progress. This exploratory study present

practical components of QA system in state DOTs and identify key factors that influence the selection of their QA approaches. These practical components will be helpful to explore how other DOTs implement their own quality management for DB projects people and their reasons why DOTs choose their approach over other approaches. However, this study limits to present the current practices and needs to evaluate the relationship among the six practical components. Also, detailed statistical analysis should be conducted to develop a decision-making process and present the relationship between decision-making factors and different approaches of the six practical QA components. Thus, this will help people who are not familiar with quality management approaches for alternative delivery projects as a guide and use for DOTs and contractors that have not actively implemented DB projects.

APPENDIX A. DETAILED INTERVIEW QUESTIONS

The initial first interview question is related to fundamental differences between DBB and DB in terms of quality management practices. After the responses of the first interview were received and materials that interviewee shared with were reviewed, the sixth round of follow-up interviews were developed afterward.

A.1 First round of Interview Question

1. Fundamentally, what is different in your quality management program in design-build vs. design-bid-build projects? Would you please send us a copy of your quality management plan for design-build and design-bid-build projects?
2. Could you please describe your quality management org chart for design-build projects? (e.g., stop-work authority, reporting lines, coordination mechanisms, approval process, decision-making, etc.)
3. What strategies has your agency used to establish good working relationships with your regional FHWA office regarding quality management plan for your design-build and P3 programs?

A.2 Second round of Interview Question

1. Does your DOT sometimes change its approach to Quality management based on specific project features, unique project goals, or Departmental concerns?

2. If yes, could you give us some examples and elaborate on how the decision has been made? What factors have been considered in the decision-making process?

A.3 Third round of Interview Question

1. Is Quality Manager considered a key personnel in the design-build team? If yes, how would you evaluate the qualifications of the quality manager in the shortlisting process? Can you please provide us with an RFQ example that shows the language used to evaluate the qualification of the design-build quality management team?
2. Is the design-builder's proposed quality management plan evaluated in the selection process? If yes, what is the scoring criteria, weights, etc.?

A.4 Fourth round of Interview Question

1. In your opinion, which approach is adopted by your DOT in design-build projects? What are the decision-making factors that go into making this determination? Is this something that changes project by project?
 - a) Project Approach: frequency of IA testing is based on a percentage of the quality control and acceptance testing.
 - b) System Approach: IA testing is done with the view to proctor all testers and equipment over a period of the year including all projects. The idea is to ensure all testers and equipment are reviewed and same testers are not reviewed continually.

- c) Mixed Approach: underlying consideration to this approach is that some tasks are better suited to project approach and should to be reviewed based on a certain fixed frequency rate and other tasks are more dependent on the equipment quality and the personnel capability.

A.5 Fifth round of Interview Question

1. Typically, what is your mechanism for budgeting QA services in design-build projects?
Is the QA budget based on a set percentage (like 3% - 4%) of total project cost? Or is it broken down based on different types of tasks that need to be performed as part of QA services?
2. Do you require the Design-Builder to spend atleast an 'X' amount or an 'X' percentage towards Quality Management tasks?
3. How does the DOT ensure that the allocated budget is spent correctly? Do you check the number of work-hours, hourly rates, invoices, etc. that a contractor spends on different tasks under the quality management services?

A.6 Sixth round of Interview Question

- Pay Factors: In traditional design-bid-build projects, several state DOTs adjust payment for line items based on the levels of quality criteria, e.g., asphalt pavement and concrete structure line items.
1. Do you implement similar pay factors in design-build projects?

2. On what line items do you consider pay factor adjustment?
3. How do you apply pay factors for design-build projects? How the adjustment is different in lump-sum design-build projects compared to that in unit price design-bid-build projects?
4. If you have any materials that describe the pay factor adjustment process in your DOT, would you please share it with us to enhance our understanding?

A.7 Seventh round of Interview Question

- Non-Conformance Reports (NCR): In DB Projects, when the contractor's quality test results do not match with the contract requirements or if there is a non-conformance,
 1. Is NCR part of your DOT's quality management plan for design-build projects?
 2. Who issues NCR? Can you describe the roles and responsibilities in the NCR process?
 3. How is the NCR reviewed, handled and resolved? If you have any materials that describe the NCR process in your DOT, would you please share it with us to enhance our understanding?

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